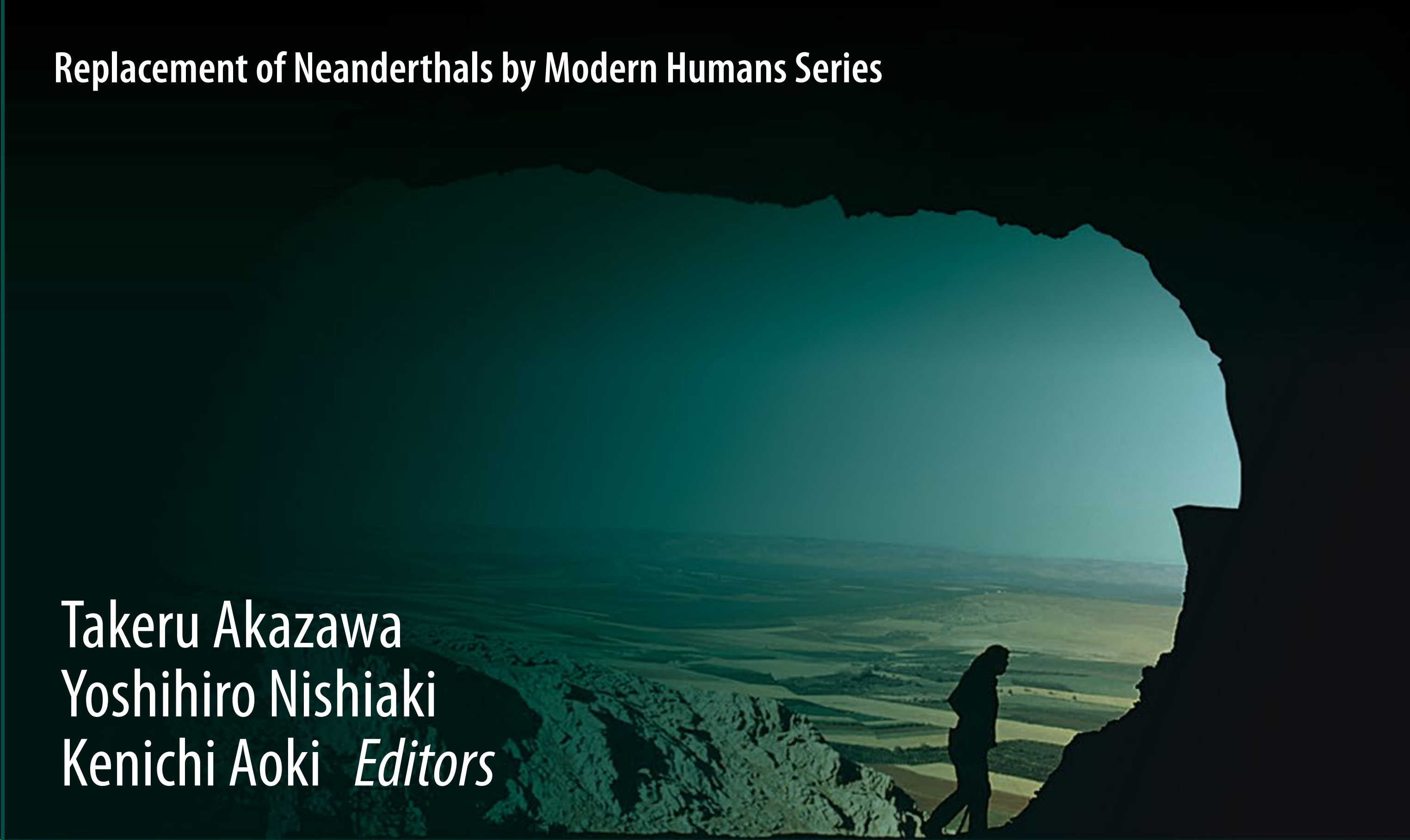
Replacement of Neanderthals by Modern Humans Series



Takeru Akazawa
Yoshihiro Nishiaki
Kenichi Aoki *Editors*

Dynamics of Learning in Neanderthals and Modern Humans

Volume 1

Cultural Perspectives

Springer

Replacement of Neanderthals by Modern Humans Series

Edited by

Takeru Akazawa
Research Institute, Kochi University of Technology
Kochi 782-8502, Japan
akazawa.takeru@kochi-tech.ac.jp

Ofer Bar-Yosef
Department of Anthropology, Harvard University
Cambridge, Massachusetts 02138, USA
obaryos@fas.harvard.edu

The planned series of volumes will report the results of a major research project entitled "Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning", offering new perspectives on the process of replacement and on interactions between Neanderthals and modern humans and hence on the origins of prehistoric modern cultures. The projected volumes will present the diverse achievements of research activities, originally designed to implement the project's strategy, in the fields of archaeology, paleoanthropology, cultural anthropology, population biology, earth sciences, developmental psychology, biomechanics, and neuroscience. Comprehensive research models will be used to integrate the discipline-specific research outcomes from those various perspectives. The series, aimed mainly at providing a set of multidisciplinary perspectives united under the overarching concept of learning strategies, will include monographs and edited collections of papers focusing on specific problems related to the goals of the project, employing a variety of approaches to the analysis of the newly acquired data sets.

For further volumes:
http://www.springer.com/series/11816

Takeru Akazawa • Yoshihiro Nishiaki
Kenichi Aoki
Editors

Dynamics of Learning in Neanderthals and Modern Humans

Volume 1

Cultural Perspectives

Proceedings of the international conference on "*Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning*", organized by Takeru Akazawa, Shunichi Amari, Kenichi Aoki, Ofer Bar-Yosef, Ralph L. Holloway, Shiro Ishii, Tasuku Kimura, Yoshihiro Nishiaki, Naomichi Ogihara, Hiroki C. Tanabe, Hideaki Terashima, and Minoru Yoneda, which took place in Tokyo, November 18–24, 2012, Volume 1.

Edited by

Takeru Akazawa
Kochi University of Technology, Kochi, Japan

Yoshihiro Nishiaki
The University Museum, University of Tokyo, Tokyo, Japan

Kenichi Aoki
Meiji University, Tokyo, Japan

Springer

Editors
Takeru Akazawa
Research Institute
Kochi University of Technology
Kochi, Japan

Yoshihiro Nishiaki
The University Museum
The University of Tokyo
Tokyo, Japan

Kenichi Aoki
Organization for the Strategic Coordination
of Research and Intellectual Properties
Meiji University, Tokyo, Japan

ISBN 978-4-431-54510-1 ISBN 978-4-431-54511-8 (eBook)
DOI 10.1007/978-4-431-54511-8
Springer Tokyo Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013956234

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Knowledge about the pathways of human evolution has expanded dramatically as a result of advances in genetic, paleontological, and archaeological studies in the twentieth century. One excellent example is the resolution of the issue of the origin of modern humans, long a source of great controversy; namely, the idea that modern *Homo sapiens* are direct related genealogically to Eurasian archaic humans was rejected, and the "Out of Africa" theory, which is now the accepted evolutionary model, was vindicated. However, this new theory only gave rise to a flurry of new questions, one of which centers on the drama of the replacement of the archaic Neanderthals by modern *Homo sapiens*.

Modern humans emerged in Africa about 200,000 years ago; as they subsequently spread across Eurasia, they encountered the indigenous Neanderthals. The two populations coexisted until 30,000 years ago or perhaps even later, but the Neanderthals eventually went extinct. What governed the fates of the two groups? A number of current hypotheses have been proposed to explore the possible mechanics of the replacement of Neanderthals by modern humans, and there has been extensive debate as to whether or not the presence of the modern humans accelerated the extinction of the Neanderthals. This question is being hotly debated among archaeologists, anthropologists, and geneticists around the world.

We are actively engaged in a five-year (2010–2014) major research project entitled "Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning" (RNMH). In launching RNMH we have adopted a large scale innovative assault on this research question. The RNMH project implements a pioneering framework structured around the contrast between the success of modern human societies in solving strategic survival problems, and the failure of Neanderthal societies to do so. In that context, we attribute the contrasting fates of the two societies to a difference in learning abilities between the two populations. This is the basis of our working hypothesis ("learning hypothesis").

The specific goal of this project is to verify the learning hypothesis within an interdisciplinary research framework incorporating new perspectives and methods in the fields of archaeology, paleoanthropology, cultural anthropology, population biology, earth sciences, developmental psychology, biomechanics, and neuroscience. The two present volumes are the proceedings of the first international RNMH conference held in Tokyo in November 2012. Some results have already been published separately in various scholarly journals, but these two volumes constitute the first full attempt to disseminate the findings of our RNMH project to the international research communities. A major purpose in doing so at this halfway point of our project is to solicit scholarly evaluation of these findings.

The 43 submitted manuscripts have been classified into seven sections based on content, and then divided into two groups to be published as two volumes in the Replacement of Neanderthals by Modern Humans series. The first volume is devoted to discussion of cultural perspectives, the second to cognitive and physical perspectives. We hope that these two volumes may contribute significant new insights on the process of replacement and on interactions between Neanderthals and modern humans, and hence on the origins of prehistoric modern cultures.

The editors of this volume are greatly indebted to all our colleagues who supported the publication with their reviews and comments: Ofer Bar-Yosef (Harvard University), Marcus W. Feldman (Stanford University), Hitoshige Hayaki (Kobe Gakuin University), Yasuo Ihara (University of Tokyo), Seiji Kadowaki (Nagoya University), Ryosuke Kimura (University of the Ryukyus), Yutaka Kobayashi (Meiji University), Sachiko Kubota (Kobe University), Steven L. Kuhn (University of Arizona), Laurent Lehmann (University of Lausanne), Wataru Nakahashi (University of the Ryukyus), Keiichi Omura (Osaka University), Akira Takada (Kyoto University), Kohei Tamura (University of Tokyo), Hideaki Terashima (Kobe Gakuin University), Joe Yuichiro Wakano (Meiji University). These colleagues read the manuscripts and made critical but constructive comments on the early drafts; this valuable input greatly improved the quality of the volume. Many thanks to all of them.

We are pleased to acknowledge the Japanese Ministry of Education, Culture, Science, and Technology for their interest in our project and for their financial support, which has made possible our RNMH Project, the conference, and the preparation of this volume.

We would like to thank Ken Kimlicka and Taeko Sato of Springer Japan for their most valuable guidance and support, and for their tireless encouragement during the preparation of this volume.

March 2013

Takeru Akazawa
Yoshihiro Nishiaki
Kenichi Aoki

Contents

Contributors

Takeru Akazawa Research Institute, Kochi University of Technology, Kami-shi, Japan

Kenichi Aoki Organization for the Strategic Coordination of Research and Intellectual Properties, Meiji University, Tokyo, Japan

Ran Barkai Department of Archaeology, Tel-Aviv University, Tel-Aviv, Israel

Ofer Bar-Yosef Department of Anthropology, Peabody Museum, Harvard University, Cambridge, MA, USA

Nicole Creanza Department of Biology, Stanford University, Stanford, CA, USA

Marcus W. Feldman Department of Biology, Stanford University, Stanford, CA, USA

Laurel Fogarty Department of Biology, Stanford University, Stanford, CA, USA

Avi Gopher Department of Archaeology, Tel-Aviv University, Tel-Aviv, Israel

Bonnie Hewlett Department of Anthropology, Washington State University, Vancouver, WA, USA

Shiro Horiuchi Center of Education Innovation, Shibaura Institute of Technology, Saitama, Japan

Seiji Kadowaki University Museum, Nagoya University, Nagoya, Japan

Hirofumi Kato Center for Ainu and Indigenous Studies, Hokkaido University, Sapporo, Japan

Yutaka Kobayashi Organization for the Strategic Coordination of Research and Intellectual Properties, Meiji University, Tokyo, Japan

Sachiko Kubota Department of Cultural-Interaction, Graduate School of Intercultural Studies, Kobe University, Kobe, Japan

Steven L. Kuhn School of Anthropology, University of Arizona, Tucson, AZ, USA

Wataru Nakahashi Department of Human Biology and Anatomy, Graduate School of Medicine, University of the Ryukyus, Okinawa, Japan

Yoshihiro Nishiaki The University Museum, University of Tokyo, Tokyo, Japan

Jun Takakura Archaeological Research Center on the Campus, Hokkaido University, Sapporo, Japan

Hideaki Terashima Department of Human Psychology, Kobe Gakuin University, Kobe, Japan

Joe Yuichiro Wakano Organization for the Strategic Coordination of Research and Intellectual Properties, Meiji University, Tokyo, Japan

João Zilhão Departament de Prehistòria, Història Antiga i Arqueologia, Facultat de Geografia i Història, University of Barcelona, Seminari d'Estudis i Recerques Prehistòriques, Barcelona, Spain

1 Introduction

Yoshihiro Nishiaki, Kenichi Aoki, and Takeru Akazawa

The processes and background behind the successful global dispersal of modern humans are among the most hotly debated issues in paleoanthropology. Many hypothetical causes for the replacement (and/or assimilation) of archaic hominid populations by modern humans—hereafter, the replacement—have been invoked, including differences in population size, technological capability, symbolic ability, cognitive fluidity, life history, and birth rate. Among these, the hypothesis referred to in this and the following volumes is concerned with cognitive differences that may have existed between Neanderthals and modern humans. More specifically, we address a working hypothesis coined the "learning hypothesis," which assumes that the replacement was due to innate differences in learning ability. Better known cognitive hypotheses include the "neural hypothesis," suggesting that modern humans acquired powerful linguistic and symbolic abilities (Klein and Edgar 2002); and a cognitive fluidity model claiming that modern humans possessed more developed fluid mentalities (Mithen 1996, 2005). More recently, Coolidge and Wynn (2009), Wynn and Coolidge (2011) have presented a hypothesis that argues for differences in working memory capacity.

The learning hypothesis represents the latest in this direction, focusing on and emphasizing a particular aspect of cognitive ability. It was originally developed to interpret differences in the rate of cultural evolution, which are frequently observed in the archaeological records of modern human and other hominid societies. In certain parts of the Old World, the Upper Paleolithic industries left by modern humans changed much faster than those of the Neanderthal-associated Middle Paleolithic. This observation may suggest that modern humans were more creative because they excelled in individual learning—i.e., learning from personal experience rather than socially from others. According to Aoki (Chap. 12), the learning hypothesis is based upon the following premises: (1) Learning abilities (strategies) of modern humans were innately different from those of Neanderthals; (2) The difference in learning strategies resulted in significant differences between the two populations in the evolution and content of culture; (3) These differences in culture and its evolution played a major role in the replacement of Neanderthals by modern humans.

Most researchers would likely be quick to accept the third premise in an attempt to verify the learning hypothesis. Essentially, human adaptation depends heavily on culture. It was modern humans who survived and expanded across the globe. Therefore, a reasonably convincing premise is that their culture, technology, and presumably other adaptive ways in which they developed in comparison to the Neanderthals were a primary cause for the replacement. Likewise, if culture and technology are considered the products of learning, the second premise should hardly be contentious. If there were indeed differences between Neanderthals and modern humans in regard to cultural adaptability, such a disparity might well have been brought about by differences in learning, although their detailed mechanisms need to be determined.

Consequently, in order to verify the learning hypothesis, it must be possible to demonstrate that different learning strategies caused differences in technology and culture.

Y. Nishiaki (✉)
The University Museum, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
e-mail: nishiaki@um.u-tokyo.ac.jp

K. Aoki
Organization for the Strategic Coordination of Research and Intellectual Properties, Meiji University, 4-21-1 Nakano, Nakano-ku, Tokyo 164-8525, Japan
e-mail: kenaoki@meiji.ac.jp

T. Akazawa
Research Institute, Kochi University of Technology,
185 Miyanokuchi, Tosayamada, Kami-shi, Kochi 782-8502, Japan
e-mail: akazawa.takeru@kochi-tech.ac.jp;
akazawa0823@qd6.so-net.ne.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_1, © Springer Japan 2013

We must also try to derive the different learning strategies from innately different cognitive abilities. Such questions are being explored in the current research project called the RNMH (Replacement of Neanderthals by Modern Humans) within an interdisciplinary framework incorporating new perspectives and methods from the humanities and biological sciences, including neuroscience and engineering. In order to introduce this research program, an international conference was held in Tokyo in November 2012. The conference successfully served as a unique multidisciplinary discussion forum on this intriguing paleoanthropological issue. For the published proceedings of this conference, we grouped selected contributions under three sections: cultural, cognitive, and physical perspectives. The papers covering cultural perspectives (this volume) address the replacement processes and learning strategies of Neanderthals and modern humans with reference to changing patterns in archaeological cultures and propose models for theoretical interpretation. The papers included in the cognitive and physical perspectives (the second volume) explore the innate differences in learning/cognitive ability that may have existed between Neanderthals and modern humans using research disciplines mainly developed in the cognitive and neurological sciences.

The present Volume 1 consists of three parts. Part I provides an archaeological overview of the replacement processes of Neanderthals by modern humans. Bar-Yosef (Chap. 2) presents his views on the social organization and lithic technology of these populations and their interaction based on the extensive archaeological records across Eurasia. The replacement is viewed as the result of modern humans' social and cultural advantages over the Neanderthals, similar to comparable events that occurred with any two other competing populations in prehistory. This introductory chapter is followed by papers dealing with specific regional evidence from Europe, the Levant, and Siberia. Archaeological evidence and dates from the latest Middle and the earliest Upper Palaeolithic sites in Europe, the best-documented region for evaluating this subject, are critically examined in Zilhão's paper (Chap. 3). Supporting the assimilation model of Neanderthals into the *Homo sapiens* population, Zilhão concludes that the available archaeological records support a scenario in which Neanderthals were capable of producing so-called transitional lithic industries and symbolic objects. Rather than focusing on replacement processes, Kadowaki (Chap. 4) examines the variability in Levantine Middle and Upper Paleolithic industries to define differences in the patterns of social and individual learning, pointing out a number of challenges that complicate this evaluation. Kato's paper (Chap. 5) covers the region of Siberia, east of the Urals, and provides a literature survey of lithic industries during the late Middle to the early Upper Palaeolithic period. Regional variability is emphasized in the processes of "transitions," which require adequate interpretations.

The last two papers in Part I provide additional considerations on the replacement. Noting the high trophic level required for Neanderthal survival, Kuhn (Chap. 6) argues that small fragmented populations was the decisive factor that resulted in slow rates of cultural evolution, weak social ties, and eventual fragility against the incoming modern human populations. Barkai and Gopher (Chap. 7) draw our attention to an example of earlier replacement that took place at the end of the Lower Paleolithic, when *Homo erectus* disappeared in the Levant. In that case, triggered by the regional extinction of elephants, the hominids' resultant dietary stress may have necessitated a range of cultural adaptations, including the adoption of new learning strategies.

Parts II and III make more direct contributions to understanding past learning strategies and their possible relationship with replacement processes. The first paper in Part II (Terashima, Chap. 8) presents a research framework for reconstructing evolutionary models of learning from cultural and social anthropological perspectives. In the field of archaeology, more effort is focused on finding evidence of prehistoric learning from the refitting of lithic artifacts and analysis of their spatial contexts. One such attempt by Takakura (Chap. 9) shows that emulation could have played an important role in learning core reduction technology at Upper Paleolithic knapping stations in Hokkaido, Japan. Nishiaki (Chap. 10) and Hewlett (Chap. 11) present ethnographic case studies of modern hunter-gatherer societies to obtain insights for recognizing the invisible evidence of prehistoric learning. Nishiaki examines the practice of giving at a village in Papua New Guinea and emphasizes its function in the cultural transmission of bow-and-arrow technologies. He also emphasizes that this issue can be tested with archaeological records, since giving can leave material evidence. Hewlett summarizes her research on learning strategies among a hunter-gatherer community in the Congo Basin, where social and individual learning showed patterned changes by an individual's age. The Hewlett and Nishiaki contributions highlight the importance of understanding life histories of the given hominid populations when comparing their learning processes.

Part III presents a collection of papers covering rigorous theoretical approaches to evolutionary models of learning. As stated in the introductory paper by Aoki (Chap. 12), evolutionary theory itself cannot demonstrate the existence of innate differences in learning abilities. Instead, it predicts what kinds of learning strategies are more adaptive under specific conditions. It can also provide insight on the significance of learning ability in relation to other factors that are advantageous for human survival. Aoki shows that the innovation rate must have been at least as important as the population size, which is often considered of primary importance by archaeologists, in determining the cultural evolutionary rate of any hominid group. The predictions made by Creanza and colleagues (Chap. 13) are concerned with the significance of cooperation and active teaching in successful cultural niche construction by humans. The significance of social contacts for advanced cultural evolution is also emphasized in an agent-based model by Horiuchi and Kubota (Chap. 14), in which ethnographic case studies of cross-cultural ritual meetings are presented. On the other hand, the approach taken by Kobayashi (Chap. 15) considers multiple factors in modeling the actual replacement processes in Europe. Kobayashi presents a mathematical simulation model to illustrate how the replacement proceeded under the premise that climate change, inter-specific group competition, and innate difference in learning abilities were all equally important. Nakahashi (Chap. 16) discusses the specific nature of learning ability and its evolutionary process. In addition to social and individual learning, he introduces a third type of learning involving the improvement of socially learned cultural traits. Termed "social improvement" ability, Nakahashi predicts that this evolved among modern humans who experienced a particular set of environmental changes. The second paper by Nakahashi (Chap. 17) investigates the contact between Neanderthal and modern human populations and its consequences in terms of cultural evolution rates. Based on theoretical considerations, Nakahashi predicts that the interaction between these two populations was minimal and, because of this, the sudden explosion of Upper Paleolithic culture occurred in Europe. This series of theoretical papers concludes with Wakano (Chap. 18), who presents a verbal synthesis of current theoretical models exploring the evolution of learning strategies and perspectives in order to enhance further collaboration with field scientists.

Readers may note differing degrees of commitment to the issues of learning abilities/strategies in the 17 papers compiled in this volume. Field archaeologists and anthropologists dealing with empirical data on past human behavior naturally encounter difficulty in validating hypotheses proposing innate, cognitive differences between Neanderthals and modern humans (cf., papers in the section on cognitive perspectives, the second volume). Kuhn highlights this difficulty by stating that archaeologists tend to focus on "demographic and social processes because they seem most accessible using archaeological data, and are at least potentially testable." Kadowaki also addresses methodological difficulties in archaeological testing. Nevertheless, given that learning is a driving force in any human culture, studying prehistoric learning strategies is essential to understanding different patterns of cultural evolution and their consequences, whether or not the cognitive ability of learning is addressed. Furthermore, testing one hypothesis inevitably entails testing and comparing other hypotheses as well, implying that research on learning should not be limited to this topic alone but should encompass a variety of other variables reflecting aspects of human behavior. Learning behavior is certainly correlated with other important variables (e.g., life history and social organization). In other words, the learning hypothesis can be considered as an effective tool for looking into past human culture in its entirety. We hope that this volume presents unique cultural perspectives on mechanisms of the replacement of Neanderthals by modern humans and the suggested relationships between these mechanisms and different learning strategies. We also hope that these volumes serve as an important starting point for developing new strategies for ongoing research on this significant event in the human past.

References

Coolidge FL, Wynn T (2009) The rise of *Homo sapiens*: the evolution of modern thinking. Wiley, Chichester

Klein R, Edgar B (2002) The dawn of human culture. Wiley, New York

Mithen SJ (1996) The prehistory of the mind: a search for the origins of art, science and religion. Thames & Hudson, London and New York

Mithen SJ (2005) The singing Neanderthals: the origins of music, language, mind and body. Weidenfeld & Nicolson, London

Wynn T, Coolidge FL (2011) The implications of the working memory model for the evolution of modern cognition. Int J Evol Biol 2011, ID 741357, 12 pages

Part I

Archaeology of Replacement of Neanderthals by Modern Humans

Neanderthals and Modern Humans Across Eurasia

2

Ofer Bar-Yosef

Abstract

Neanderthals, a European population was undoubtedly successful in surviving through several glacial periods. Their population, originally spread across Europe, composed of small communities but succeeded to maintain their relationships and their mating systems and thus secured their biological survival. Published samples of aDNA and teeth indicate that they formed a particular population, although morphological deviations from the western European relics are found at the edges of their geographic distribution. The expansions of Neanderthals into western Asia and reaching the Altai Mountains reflect their successful adaptations to variable environments. Their demise was caused, among others, by the expansion of groups of modern humans of African origins. The cultural traits of the new invading and colonizing people included high degree of mobility, signs of group identity, new cloths, use of ornaments, new hunting tools, and means of communication. The interactions of modern humans with the Neanderthals, discussed in the paper, provide a foundation for further research along economic and biological considerations that may provide a more sound explanation for the disappearance of a past successful meta-population.

Keywords

Eurasia • Expansions • Modern humans • Neanderthals

2.1 Opening Remarks

This paper approaches the issue of Neanderthals and Modern humans as the story of two competing prehistoric meta-populations, a situation that probably occurred to other populations during the long sequence of human evolution. It is also a sort of an eclectic summary of my personal thoughts and comments that I gathered while being involved in this important evolutionary topic. Therefore this is not a comprehensive summary concerning Neanderthals and modern humans; rather it is my current view.

O. Bar-Yosef (✉)
Department of Anthropology, Harvard University,
Cambridge, MA 02138, USA
e-mail: obaryos@fas.harvard.edu

During the last two decades I felt that rarely scholars who study human groups since they emerged as "tool makers" discuss issues of human extinctions. The underpinning positive attitude embedded in the study of palaeoanthropology and prehistoric archaeology masks the question of what happened to those whose discarded artifacts and kitchen debris who are identified by us as representing different groups of foragers, and their time-length of survival is based of radiometric dates. Gaps in stratified sites indicate that they disappeared within several thousand years. In our interpretations we are limited in naming the humans themselves but use the labels given to their fossil bones. Another difficulty in our interpretations is that we often assume that Paleolithic human relics found in archaeological contexts were also the makers of the stone tools. Thus we find it an uneasy question to ask "how" the taphonomic processes in the formation of the site

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*,
Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_2, © Springer Japan 2013

or a particular layer resulted in the observed combination of stone tools with fragmentary human bones. Site formation processes is one of the under-studied and poorly understood in prehistoric archaeology. Although major progress was made in recent decades through the use of micromorphology and other methods, we are far from having objective, scientific interpretations of how assemblages of bones and stones became an entity in stratified sites (e.g., Goldberg and Macphail 2006).

The cumulative experience of archaeologists during the last century and a half has demonstrated that human fossils are few and isolated, or missing altogether, but the concrete evidence for their existence are the cultural remains that were subject to changes, and sometimes to total disappearance due to geomorphic processes or modern development. Past human activities are thus observed through the analysis of their lithic assemblages and animal bones, and occasionally by additional remains such as bone, antler and ivory objects, wooden artifacts, fire-wood, edible plants and body decorations. The clues for identifying human groups in the past are therefore minimal. Most informative are the different ways of making stone artifacts, systematically recorded in the operational sequences (*chaïne opératoire*). This kind of analytical method assists us in relating lithic assemblages to particular prehistoric groups or populations (e.g., Lemonnier 1976, 1992; Boeda et al. 1990; Boëda 1995; Bar-Yosef and van Peer 2009 and references therein). We interpret this information as flagging the tradition of teaching and learning processes among past societies that often lasted through many generations. However, when a major change is documented we often tend to assume that the "transition" or the "shift" took place within the same population although it may or may not indicates a "replacement" caused by the arrival of new people. This kind of interpretation is essential for the discussion of "Neanderthals and modern humans" although with evidence for a certain degree of interbreeding (e.g., Green et al. 2010), past heated debates are reduced to the practical questions of "when" and "where." Yet each of these two meta-populations was composed of different groups thus motivating me and other colleagues to identify each "culture" and reconstruct its "history." Therefore the foundation for such investigation lies in the traditional anthropological methods and cumulative observations concerning life ways of hunting and gathering societies, as well as in-detailed knowledge of how stone tools and other objects were made and used. It is not an accident that the term "prehistory" means people without history, including some who lived dring historical periods (e.g., Wolf 1982).

There are many observations to support "cultural breaks," often documented by stratigraphic gaps that occurred despite various subsistence options and survival strategies. Moreover, there is a wealth of evidence to demonstrate that our definition of "cultural continuity" in the sense of biological continuity existed during the Lower and Middle Pleistocene. Similar records of Upper Pleistocene age are retrieved in several regions in mid-latitudes, such as the long-term survival of Neanderthals even in spite of worsening climatic conditions such as those of the glacial cycles. What we do not know is how many groups of this meta-population became extinct because others survived and enabled the preservation of the genetic basis. Similarly, the debated issue of "replacement" may indicate that the new meta-population of modern humans took over many territories. A few examples from well-known Paleolithic records will illustrate this phenomenon although their selection here is not necessarily in geographical or chronological order.

Eclectic examples for "replacement" or "turnover" include the Bohunician in Moravia (e.g., Svoboda 2005), in Crimea by Upper Paleolithic groups of blade makers (e.g., Chabai 2003, and references therein; Chabai and Monigal 1999). Further east, on both sides of the Caucasus mountains similar groups of bearers of blade/bladelet industries replaced the locally two different Mousterian industries (e.g., Adler et al. 2006, 2008; Golovanova and Doronichev 2003; Golovanova et al. 2010). In the Levant an earlier replacement of the Acheulo-Yabrudian by the Mousterian ("Tabun D-type"), produced technically Levallois industries, as recorded in the occupations of Tabun, Zuttiyeh, Hayonim caves (e.g., Hovers 2006; Hovers and Kuhn 2006 and papers therein; Shea 2003); In the Maghreb in North Africa the Aterian was replaced by makers of microlthic industries such as the Iberomuarusian; South Africa produced a good example with the disappearance of the Howeison's Poort and the re-occupations by bearers of late Middle Stone Age industry (Wadley 2001, 2008; Jacobs et al. 2008; Villa et al. 2010), and then by blade/microlithic industries of the Late Stone Age (Deacon and Deacon 1999).

All these replacements took place regardless of close sources of good quality raw materials and the continued exploitation of essentially the same or similar faunas and plants. Therefore, in my current view, these cases are examples for "moving in" and "pushed out" of different populations, or competitive exclusion. The variable survival of particular cultures is intriguing because it creates an evolutionary cultural puzzle that is hard to decipher due to many missing pieces of information. Examples include several cultures dated to the Late Middle and Upper Pleistocene which lasted 4–8 Ka (e.g., the Aurignacian in Europe or the Kebaran complex in the Levant) or 10–20 Ka (e.g., the Howiesons Poort), versus those that lasted 40–80 Ka (e.g., early, middle and late Mousterian in the Levant, Mousterian of Acheulian Tradition, etc.) However, it is still one of our missions as archaeologists to try and explain the variable survival time of these well-dated and in-depth studied cultures as defined on the basis of their lithic industries.

On the optimistic side, there are cases when people survived as makers of essentially the same stone tools regardless of shifting climatic conditions such as the glacial cycles. These include various different groups of Neanderthals in Europe, Lower and Middle Paleolithic "core and flake" makers in China, the Acheulian of India, Mousterian industries in the Levant, and more. Perhaps the safer conclusion would be that when human groups were smaller, less dense over the landscape, but still in touch within their meta-population for securing reproduction, changes were not needed, expected or expressed in materials that were not preserved. However, as the number of people grew, migrations of foraging groups were feasible, the spread of the same industries took place, splitting populations changed their tool-kits, in the same way that a language, once removed from its original homeland, develops dialects or even turns into new languages.

Western Europe is undoubtedly still the best studied region, rich in archaeological documents that demonstrate the relatively rapid changing technical and typological variability within stone, antler, bone and ivory tools, figurines and body decorations from ca. 45/40,000 to 11,000 years ago known as the Upper Paleolithic (Klein 2009). Whether this richness emanated or encouraged by local conditions (social? climatic? increasing densities of people?) is an open question. Undoubtedly the region enjoyed the favorable Atlantic climatic conditions and thus served as a home for locals and as a desired refugium for foreigners who moved in from different directions from time to time.

In sum, we often adopt an interpretation that claims that when the subsistence strategy changed dramatically, humans opted to change their stone tools. However, in more than one example the production of the same tools, designed by essentially the same operational sequence(s) continued after the crisis supports the conclusion of biological continuity. When no changes of paleo-ecological conditions are documented, we view major shifts in the artifact assemblages as evidence for the presence of "new people," or do our best to disclose how employing new tool making techniques occurred within the same population and define it as a cultural "transition."

However, in a few cases, due to terminological conundrum and old excavation techniques, often derived from the work of previous generations of archaeologists, we are unable to interpret the past. Unintentionally the terms originally created in need to classify the finds in a relative chronology, mask important variability. Labels such as "Middle Paleolithic", "Middle Stone Age" or "Mousterian industry" that we often use (as in this paper) are today meaningless as much as the word "transportation" that without specifying the means of transport would include everything from horses to bicycles, cars, trains, boats and planes.

The following comments refer only to social and cultural issues derived from observations and reports on stratigraphies and lithic assemblages. I refrained from summarizing the full range of daily activities of either Neanderthals or modern humans. I will not discuss their subsistence systems, whether the amount of meat surpasses the plant food, or the techniques of hunting, trapping, use of fire, clothing, body decorations, and more. Reviewing all these aspects requires a wider in-depth summary of the available literature and is beyond the main scope of this paper.

2.2 Neanderthals: Social Organization and Geographic Expansion

Neanderthals are known as a European population that emerged some 400–200,000 years ago or earlier around 600–400,000 years. They were undoubtedly a successful meta-population surviving through several glacial periods across most of Eurasia. Their remains include human fossils (buried or as isolated bones and teeth), food refuse (mostly bones, rare plants), preserved hearths (in particular conditions such as the Mediterranean basin), and most commonly plenty of stone tools. The information was collected since the mid-Nineteen century through the excavations of numerous sites and the published reports are available in many languages. Traditionally, archaeologists attributed the Neanderthals to the time known as the "Middle Paleolithic," a term coined in the same century when, in the absence of radiometric dates, the Paleolithic was subdivided into three main phases (Lower, Middle and Upper Paleolithic).

For a long time Neanderthals were thought to have evolved into modern humans called Cro-Magnons, after the discovery of a modern human skeleton in a rockshelter in Southwest France, excavated in the mid-nineteenth century by the common crude techniques of that time, but was recently dated to a historical period. In due course during the late nineteenth and the early twentieth centuries several hypotheses were suggested to explain how and when did this evolutionary stage happened. Evidence of both physical and cultural remains was employed for this purpose. This is a major issue generally referred to as the "Middle to Upper Paleolithic transition" which is still under discussion in recent decades. Today, however, the genetic evidence clearly indicates that this "transition" was more a "replacement" of one population by another one, although it is accepted that both the old and new populations could have interbreed (see below). In addition, radiometric dates indicated that both populations were contemporary in various regions of Eurasia (see below) possibly for several millennia.

It is generally assumed that Neanderthals lived in small communities that were spread over large territories but succeeded to maintain their mating systems and through secure through close relationships their biological survival. When viewed through the few published samples of aDNA or their teeth across Eurasia it seems that these samples represent

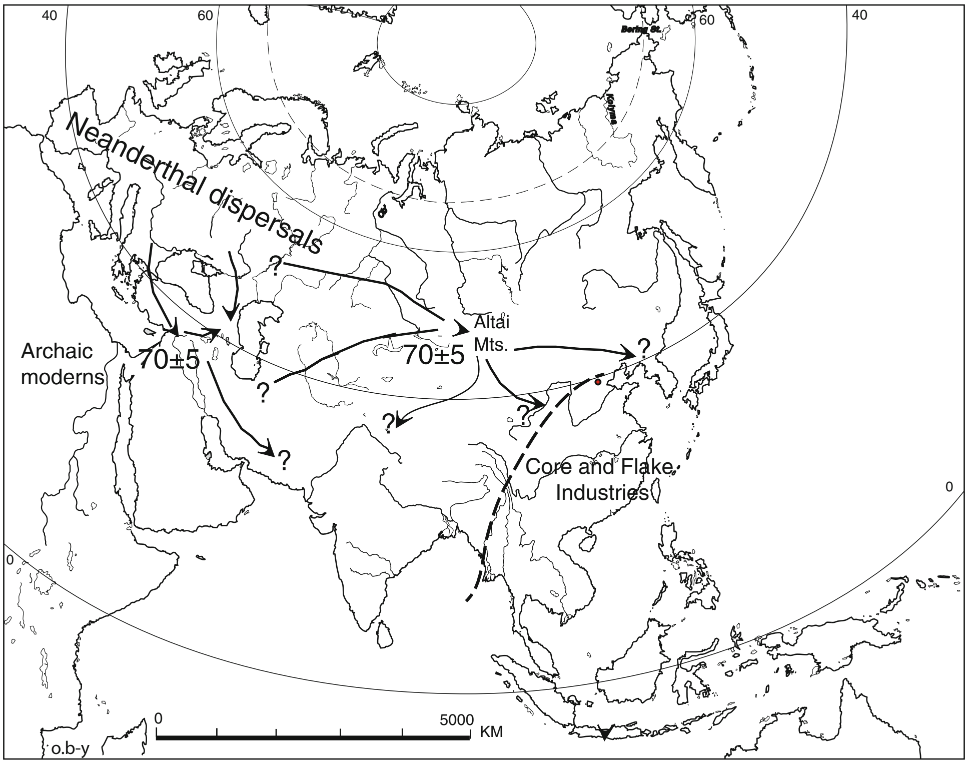


Fig. 2.1 The expansions of Neanderthals across Eurasia

a particular population (e.g., Krause et al. 2007; Bailey and Hublin 2006). However, deviations of morphological attributes between the "classical" Neanderthals from western Europe were generally found at the edges of their spatial distribution, assumed to represent either different environmental conditions or a degree of interbreeding with archaic modern humans (e.g., Arensburg and Belfer-Cohen 1998; Trinkaus 2007).

Like similar successful populations in human history Neanderthals expanded their "tribal" territories beyond their European "homeland," raising the option that their group sizes were after all not so small, or they had some effective means of communication (Fig. 2.1). Their presence in western Asia is fully supported by the Levantine fossils (dated to post—80/70,000 years ago) uncovered in Dederiyeh, Amud, Tabun and Kebara caves. Further east several skeletons turned up in the excavations of Shanidar cave in the Zagros mountains (northern Iraq), a skull fragment found in Sakjia cave, in the southern foothills of the Caucasus, as well as the human burial in Mezmaiskaya cave (Russia), on the northern slopes of the Caucasus, Teshik Tash in Uzbekistan and further east in caves of the Altai mountains.

2.3 Stone Tool Kits of Neanderthals

We often identify the so-called Middle Paleolithic stone tool assemblages, first studied, during many decades in Europe, on the basis of technological (various core reduction techniques) and typological aspects (i.e., blanks that were shaped into tools). Among the latter archaeologists define side scrapers and points, shaped by retouch, some of which were made of thicker flakes and were constantly resharpened such as the scrapers of the Quina type (e.g., Bourguignon 1996). Special types are handaxes, large and small, considered as indicating cultural heritage from the earlier European Acheulian Complex, sometimes used a "cores" (e.g., Soressi 2002; Soressi and Hays 2003), and foliates that could be seen as improved versions of bifacial objects (*kielmesser*) used as knives, mostly common across northern Europe (e.g., Jöris 2006).

Recent studies in Southwest France expose an interesting view where four different industries characterized by their operational sequences and patterns of mobility, seem to be partially or fully contemporary. The new scheme resembles the original proposal of F. Bordes (1961) who suggested to see the different industries as representing different tribes. Although the new investigations deviate to a degree they benefitted from the wealth of data accumulated during the last 50 years (e.g., Meignen et al. 2009; Delagnes and Rendu 2011). The four groups are named as (a) Levallois and Laminar flaking system, (b) Mousterian of Acheulian Tradition (MTA) shaping system, (c) Quina falking system, and (d) Discoidal-Denticulate flaking system. Chronologically (based on Table 2.1 in Delagnes and Rendu 2011 with my minor modifications), the first group survived from the end of MIS6 through 40/38 Ka BP.

Table 2.1 The new characteristics of upper Paleolithic times

A. The nature of the new economy and social strategies
– Improved subsistence strategies with new techniques and tool types
– New hunting devices—spear throwers, earliest archery? boomerangs?
– Improved clothing, especially the kind needed in the northern latitudes
– Use of grinding stones for food processing
– Increased number of exploited raw materials such as antlers, ivory and bones, special hard rocks
– Long distance procurement of raw materials and quarrying activities
– Improved systems of long distance intergroup communication
– The invention of seafaring vessels
B. Short term results
– Increased rate of survival of newborns
– Prolonged survival for the elders of the group
– Better planning depth of subsistence strategies (due to increase in monitoring larger environments)
– Changes in the intensity of symbolic behavior reflected in the new expressions of self-awareness, intra and inter-societal attitudes, rituals, etc
C. Long-term results
– Selective advantages in long term monitoring the environments expressed in the prolonged "living memory" of the group
– Formation of long-distance alliances
– Increased rate of technological adaptations to specific regional environment (e.g., the formation of regional cultures identified by their tool-kits)

The MTA lasted from about the start of the MIS 4 (ca. 75/70 Ka BP) to ca. 40 Ka but seems to have deeper roots in the Micoquian of an age earlier than MIS6. The third group, the Quina type, dates to ca. 65 Ka through ca. 40 Ka BP, and the last one, dominated by discoidal cores and denticulates, considered to have deeper roots, perhaps from MIS5 through ca. 40 Ka BP.

The search for the original appearance of the industries is definitely important and would be difficult to resolve without stratified sites. However, another possibility is that similar operation sequences could have been invented at an earlier age and then disappeared when the makers died out. In addition, the established chronologies for three groups from the cold period of MIS4 to the arrival of modern humans sometime around 43/40 Ka BP could be explained as the presence of three different tribes, speaking their own languages and follow their own particular subsistence system, while physically being all Neanderthals. This interpretation, enhanced by the information for those "Middle Paleolithic" industries from central and eastern Europe (e.g., Conard and Fischer 2000; Burdukiewicz 2000), support the notion that they were all within the meta-population of Eurasian Neanderthals.

The European research achievements recognized prehistoric "culture (s)" based on the technical expressions of people who kept manufacturing their traditional artifacts regardless of environmental fluctuations can be trace across Asia. For example, the evidence from the Altai Mountains caves (e.g., Derevianko and Shunkov 2002; Derevianko and Markin 1995; Derevianko 2011) includes lithics, fossils and aDNA of Neanderthals (Krause et al. 2007). However, the recent surprise brought by this type of biological analysis was the discovery of an unknown population called the Denisovans (Reich et al. 2011). Thus, if we assume that the correlation between fossils and lithic industries prior to the arrival of modern humans is rather simple, we face the challenge to uncover the culture of the Denisovans.

A similar situation occurred within the study of Middle Paleolithic fossils in the Levant known from the 1930s. The Levantine Mousterian Complex, a field of prehistoric research I know better, is currently divided into three industries, often uncovered in a stratigraphic order from about 220/250,000–50/47,000 years ago, and are known as "Tabun D-type, C-type and B-type" or as Early, Middle and Late Levantine Mousterian. Each of these entities survived for a long time keeping their technological traditions (Ronen 1995), whether employin one or several Levallois methods (Meignen 1998a, b). The assemblages of the Late Levantine Mousterian, rich in Levallois triangular points, contained burials and remains of local Neanderthals (e.g., Dederiyeh, Kebara, and Amud caves as well as layer B in Tabun cave). These fossils differ in their skull morphology from the "classical European Neanderthals." But the main surprise occurred already in the 1930s when the fossils uncovered with "Tabun C-type" (Middle Mousterian) assemblage in well arranged graves in Skhul and Qafzeh caves. These humans classified as a type of archaic *Homo sapiens* or near-modern humans, and once even labeled as "Proto-Cro-Magnons," were considered until the early 1980s as the ancestors of modern humans. Todate no identifiable human remains associated with the Tabun D type assemblages. Perhaps they were "near modern" (or archaic modern) humans, but further discussion of this issue is beyond the scope of this paper.

The human groups who occupied the Taurus, Zagros and southern Caucasus mountain areas made industries rich in retouched pieces (scrapers and points). They differed from the sites on the northern slopes of the Caucasus, represented by the finds from Mezmaiskaya cave, where the tool kits contained the small bifaces or foliates and were part of the Eastern Micoquian known from the European plains.

Further east the Neanderthals are found in Uzbekistan, Siberia and their industries near the Yellow River (Qu et al. 2012). It is hypothesized that Neanderthal remains (or perhaps the Denisovans) should be expected in northern China (Bar-Yosef and Wang 2012). Thus, in a growing number of geographic regions we already recognize territorial boundaries of Neanderthal groups (cultures? tribes?) across Eurasia.

In reconstructing the operational sequences employed by Neanderthals, and their contemporaries, we face the practical issue of interpreting the detailed recorded lithic products. One question, in the face of lack of detailed refitting is how to identify the knapper's intention?. I suggested that the first third or half of the detached blanks that follow the removal of the cortex are essentially the desired products. Therefore the morphological type-list of the cores found in the excavated context reflect their status as discarded products by the experienced knapper as well as their use by others. One real life option, when we consider the role of children watching adults making stone tools, is that the children would try to imitate their actions. Possibly, for the purpose of teaching the adults demonstrated how to do the first stage of knapping, all the youngsters learned how rocks could be fractured. Thus, quite often, in the counts of core types, a certain amount that does not fit the main operation sequences could represent children's activities and/or expedient use of the residual cores. For example, when two thirds of the balnks and a major portion of the rocks would fit the "convergent Levallois method" the remainders that would fall under the category of "discoidal cores" may represent teaching and/or children activities.

Moreover, a particular degree of skill is needed to practice the various Levallois methods (e.g., Boëda et al.1990; Boëda 1995) with the recent current additions (Meignen et al. 2009). When replicating past activities we recognize that particular methods take between many hours to several months of training to achieve the desired shapes of blanks such as the symmetrical Levallois triangular points (e.g., Eren et al. 2011, 2012). Thus we should consider the hypothesis that people with knapping skills had a special social place within their own society be they Neanderthals or modern humans.

2.4 Modern Humans: Some Interpretation of Their Evolutionary Advantages

It is important to remember, for historical reasons, that prior to our enthusiasm about the advances in molecular, nuclear and in particular aDNA that the "out of Africa" of modern humans was already suggested by earlier scholars such as W.W. Howells (1974). Today, following the pioneering paper of Cann et al. (1987) the estimates for this event are around 60–50,000 years ago. Several migration paths leading into Eurasia were suggested (Fig. 2.2). The southern one that ended with humans landing in Sahul is thought to be the earliest. The northern one led through the Levant or across south Arabia, through the Zagros mountains and beyond the Caspian Sea into central Asia. Another route employed the Levantine corridor and then into Europe and possibly had an eastern branch leading to the Caucasus region and in tow sideways around the Black Sea (Fig. 2.3).

The new people were culturally different as expressed In the European sites by the prehistoric records of the Upper Paleolithic that we employed for many years as a model for modern humans. True, it is still the best studied and most detailed for a region that in a global scope is quite small. The Cro-Magnons, as modern humans, were considered as the authors of the Upper Paleolithic stone tool assemblages first identified by Abbé H. Breuil (1913). He defined what we would call today a "cultural complex" named "Aurignacian." Later he realized that the three subdivisions of Early, Middle and Late Aurignacian would be better defined as three different cultures, namely, Châtelperronian, Aurignacian, and Gravettian. The later French Upper Paleolithic entities were the Solutrean, Magdalenian and Azilian. Each of these cultural units was characterized by the presence of particular tool stone, bone and antler tools ("*fossil directuer*"), and ornaments. Mobile art objects such as figurines and the increasing number of caves with rock art, located in the Franco-Cantabrian area, were attributed to the Aurignacian and all the ensuing cultures, and were considered as indicating the cognitive capacities of modern humans. Thus they were seen as our direct ancestors (e.g., Klein 2009).

Adopting the definitions of this cultural sequence to other regions across Eurasia caused confusion and unnecessary generalizations about modern humans and their cognition. For example, not all humans painted caves even when such localities exist and in abundance (e.g., compare the Franco-Cantabrian region to the western Caucasus). Making plenty of bone tools is not necessarily a sign of particular modern behavior. Even when where various deer species were available, antler tools could be rare (compare, for example, western Europe to East Asia). We should not hold as an assumption that the availability of natural resources such as suitable rocks for knapping, certain animals that can be hunted, trapped or caught by nets were always exploited following an optimal design. Undoubtedly for biological survival people would use the approach of "optimal foraging." But competition with other groups, abrupt climatic changes, failure of procurement techniques, and more may cause deviations. The results in a various cases could be disastrous. Thus "cultural breaks" are recorded across Eurasia and evidence-supported instances of such shifts should be given second thought of what could have happened.

We often attribute a series of cultural traits to modern humans although not all formed a real "package" and a good number emerged in earlier period mostly in Africa (e.g., McBrearty and Brooks 2000; Henshilwood and Marean 2003). However, in spite of the early making of bone objects or clear

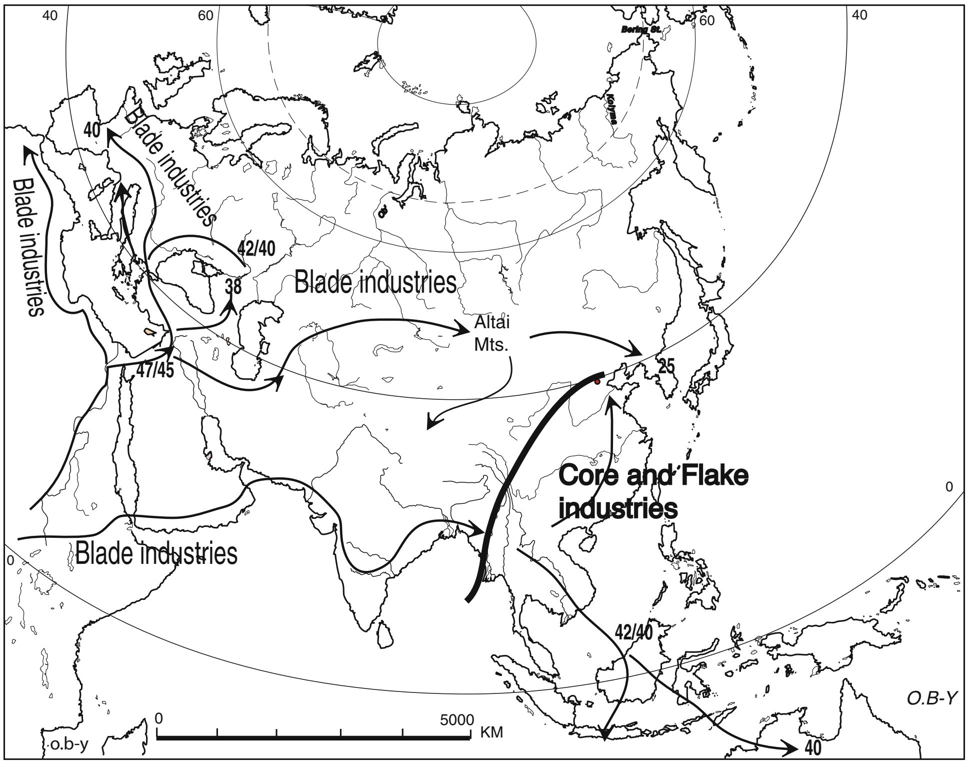


Fig. 2.2 The expansions of modern humans across Eurasia. Note that early colonization of Sahul was done by bearer of core and flake industries

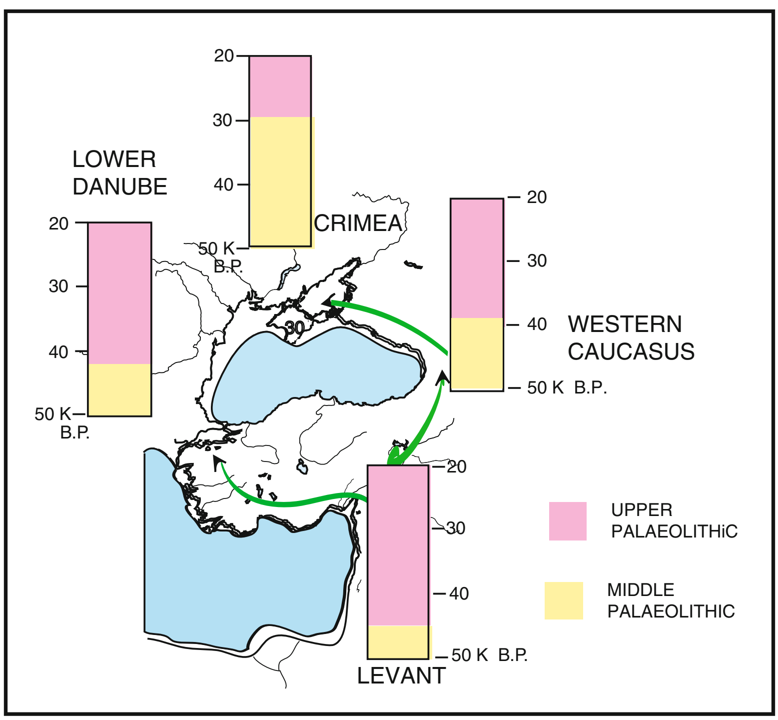


Fig. 2.3 Replacement of Mousterian industries by Upper Paleolithic early blade industries around the Black Sea

signs for symbolic behavior, the major cultural shift in the lithic industries was recorded in the Levant, across Europe, or other regions such as the Caucasus area and the Altai mountains, and took place in a short time of a few millennia beginning by 47/45,000 years ago.

The main changes that took place during the first several millennia in Eurasia and mark the onset of what traditionally we name as the Upper Paleolithic is presented in Table 2.1 (Bar-Yosef 1994, 2000, 2002; Kozlowski 2004; Kuhn et al. 2004; Lewis-Williams 1997; Vishnyatsky 2005). I feel that this list of changes and/ or innovations, probably improved along the routes of expansion/migration, describe the advantages of modern humans over the Neanderthals.

Several of these cultural-technological traits mentioned above were recognized earlier in the African records (McBrearty and Brooks 2000). Others seem to appear in the Upper Paleolithic contexts of Eurasia. For example, grinding stones appear first in the Japanese archipelago (ca. 40/35 Ka cal BP), and later in the Levant (ca. 30–26 Ka cal BP).

At the time of writing my 1994 paper I did not pay attention to the issue of languages and dialects and only implicitly considered the impact of education. A few years later I realized how much teaching and learning processes impact the degree of technical traditions (Bar-Yosef 1998). The investment in teaching and learning social skills, and survival techniques takes extra effort, and prehistoric societies guarded their traditions for many millennia. Both social traits and the making of objects determined success and failure in biological survival. Hence, abrupt or even slow climatic changes may not have had real effect on how people made their stone tools, how they used their well-established operational sequences, or the morphology of the desired objects that were mostly “carpentry-kitchen” equipment, with a few projectiles.

Environmental conditions provided the means (abundant plant and animal food stuffs) to support the basic structure and size of a population but and favored a minimal increase in numbers, causing successful populations to expand. Infrequently they migrated into empty territories, such as the Americas, or the northern latitudes of Eurasia. However, sometimes they moved into areas inhabited by other forages. Then “foreigners” and “locals” could either ignore each other, or adopt variable interaction modes whether peaceful or violent. Undoubtedly, certain interbreeding in a small number of cases was an option now shown through the aDNA studies. Thus, although one may expect that lithic techniques would be part and parcel of such interactions, demonstrating the process of acculturations in the archaeological records is not an easy task. This is exemplified by the ambiguous interpretation of the Châtelprronian culture in the French records which is briefly described here.

In the 1950s a rich assemblages of ornaments, bone objects, isolated Neanderthal teeth and a fragment of a temporal bone were found in a context attributed to the Châtelprronian recorded in the excavations conducted by A. Leroi-Gourhan in Grotte du Renne (Zilhão and d'Errico 2003 and papers therein; Zilhao et al. 2006). This discovery was reinforced in the early 1980s with the finding of a Neanderthal secondary burial apparently in a similar context of stone artifacts in St. Cesaire (Lévêque et al. 1993 and chapters therein). Thus the early Upper Paleolithic culture became known as the product of Neanderthals who either invented the making of body ornaments or learned how to make them from incoming modern humans. In brief, the options are independent invention or acculturation. Questions concerning the validity of the published stratigraphies including the role of taphonomic processes and human activities in the formation of the excavated deposits of the two sites, were not asked until recently (e.g., Higham et al. 2010; Bar-Yosef and Bordes 2010). Adherents to the old interpretations responded by repeating essentially the two past interpretations and by adding the distribution of objects and another series of dates (Hublin et al. 2012, and references therein), but not by providing a full report with, for example, the counts of artifacts. Thus the previous suggestion to view Châtelprronian as the result of acculturation by Neanderthals who interacted with modern humans is still the favorite interpretation by many (D'Errico et al. 1998, 2003; Zilhao et al. 2007; Hublin et al. 2012). The option that the Châtelprronian was simply the culture of modern humans who took over the sites of Neanderthals, as done by previous occupants of rockshelters and caves, was not suggested. The meaning of why in Grotte du Renne the Châtelprronians dug into the earlier Mousterian deposits, and produced, in addition to their lithics, a very rich assemblage of body decorations and other objects, possibly indicating the place of a shaman, was not even considered.

Most populations of modern humans grew in numbers and were technically successful. Indeed, like their predecessors in Eurasia they took over new territories by expanding in the same way as was done by the Neanderthals. A good example is the Western European Aurignacian culture, rich in artistic objects, ivory, antler, and bone industries, that emerged in the west and expanded eastward (e.g., Bolus 2003; Kozlowski and Otte 2000; Bon and Bodin 2002; Teyssandier 2008; Conard 2006). A few groups reached the coastal Levant and are characterized by their stone tools and especially by rare and typical split based points (e.g., Bar-Yosef and Belfer-Cohen 1996; Belfer-Cohen and Bar-Yosef 1999; Bar-Yosef and Zilhao 2006; Kuhn 2003). However, in all these cases we should ask what happened to the local inhabitants? Notoriously evidence for violence such as projectiles embedded in human bones are hard to find even in later periods.

Several modern human groups practiced both semi-sedentary settlement pattern as well as high degree of mobility. They produced signs for group identity, and use of ornaments. Thus, they were capable of symbolic behavior that is expressed in the Franco-Cantabrian region by cave art, mobile art objects (found also in other regions), and in a few localities open-air rock art such as the CÔa valley in Portugal.

Spatial arrangements including hearth, use of rocks for warmth banking, are cited as typical features of sites of modern humans but are also found in Neanderthal sites. Higher degree of efficiency in hunting and attributed to better hunting tools, use of nets, perhaps early use of poison and more. Among the lithics we often stress the blade making which requires different skills than producing the Levallois products through a change in conceiving the volume of the nodules as cylindrical instead of "flattish," but these attributes more common in western Eurasia than in central or eastern Asia. In addition, the making of blades as we demonstrated is a reduction sequences that appeared and disappeared in earlier times (Bar-Yosef and Kuhn 1999) but became constant during the Upper Paleolithic whether for the production of blade by direct percussion, with the use of a punch or by pressure flaking. It is important to mention that not all modern humans made blades as, for example, the colonizers of Australia some 45,000 years ago produced flake tools while blade making arrived there only in the Holocene (Habgood and Franklin 2008). Not all modern humans groups shared artistic expressions, and similarly, shell beads that were already shaped in a few Middle Paleolithic contexts and are suggested to herald self-awareness, were not common in all Upper Paleolithic sites.

2.5 Interactions Between Neanderthals and Modern Humans

In reviewing the interactions between the two populations we need to take into consideration the continental-wide archaeological information concerning the lithic industries of local Neanderthals. The best records are available from all over Europe and western Asia. The main discussion here revolves around the contemporaneity between the two populations and in this context some earlier observations that once were interpreted as either the evolution of Neanderthals into modern humans or evidence for mixing between the two populations, should be briefly mentioned. Among the previous studies one should mention the analysis conducted by Thoma (1965) who recognized some traits of modern humans among the Neanderthal fossils. Another effort to explain the change was done by Gilman (1984) who proposed an economic shift on the basis of Marxist analysis.

However, contemporaneity among prehistoric populations is an issue dealt with from Lower Paleolithic (e.g., Calctonian and Acheulian) to Holocene sites in the Maghreb to mention just a few examples (e.g., Ashton et al. 1994; Rahmani 2004). Thus, in reviewing the changing climatic and social conditions during the second part of the Upper Pleistocene we may get some clues for the contemporaneity of both populations as well as indications for the demise of the Neanderthals.

We already know from numerous European investigations that the Neanderthals in temperate Europe responded to climatic calamities by shifting and expanding their territories into western and central Asia. During the cold period of MIS4 (ca. 75–60/57,000 years ago) Neanderthals in the north European plains either died out or moved into refugia in southwest and southeast Europe resulting in the depopulation of a large region (Bar-Yosef 1988; Hublin and Roebroeks 2009). Indeed, contrary to the prevailing views of the last decade that their demise was due to climatic fluctuations during MIS3 (e.g., Gamble et al. 2004) or the effects of the Campanian volcanic eruption in Europe (Golovanova et al. 2010), recent studies indicated that both hypotheses are wrong and instead supported the interaction with the colonizing groups of modern humans (Lowe et al. 2012). Even the worsening conditions towards the end of the MIS3 did not cause the disappearance of the Neanderthals but their demise was determined by the activities of the new migrants-the modern humans (Figs. 2.4 and 2.5). However, during this time interactions between the two meta-populations took place in various regions and included among other competition for the better resources, which explains the presence of their genes in recent populations from the Atlantic coast to the Pacific (Bar-Yosef 2011).

When modern humans interact with local Neanderthals we may detect some evidence in the archaeological assemblages. It was already suggested that in Central Europe the Szeletian culture of the Neanderthals indicates the adoption of the technique of detaching blades from prismatic cores (Svoboda 2005). This observation is supported by the partial overlap of the Bohunician and Szeletian dates. The same conclusion holds for the so-called Danubian Szeletian located in the path of modern humans moving around the western side of the Black Sea. A similar case is the Jerzmanovician entity in Poland that is rich in foliates and dates to the same period. For example, the Krakow-Zweirzyniec with its proliferation of arched back blades (ca. 36–28 Ka BP) could indicate the presence of modern humans (Kozlowski 2000).

Further east there is seemingly additional evidence for interactions between these two populations in the area of Kostenki, the middle Don River area, and Crimea (Chabai 2003, 2007; Marks and Chabai 2006; Anikovich et al. 2007). The observed variability of lithic industries led researchers to propose that the Mousterian of Western Crimea and the Eastern Micoquian represent Neanderthal groups in this resource rich peninsula. Radiocarbon dates of both entities demonstrate a high degree of contemporaneity (36–28 Ka according to Chabai 2003) between the Streletskaya (ca. 36–27 Ka) and the Spitsynska (ca. 36–32 Ka) "cultures." The Streletskaya entity contains bifacial points resembling typical arrowheads, foliates, discoidal cores and "flat faced" opposed platform cores that resembles the "Eastern

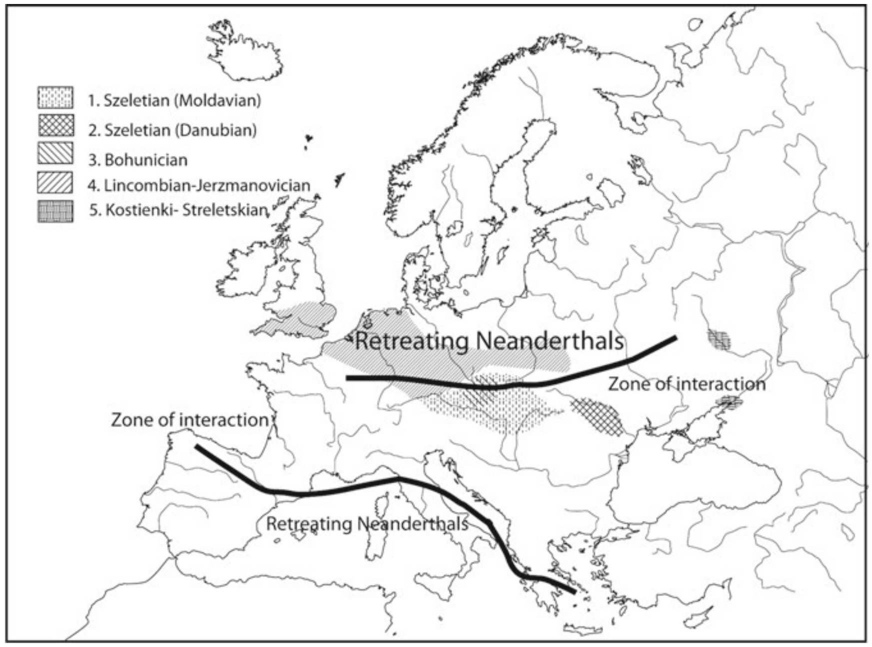


Fig. 2.4 The retreat of Neanderthal across Europe in both southern and northern directions and locations where archaeological evidence indicates acculturations. The basic map of different Middle Palaeolithc industries is courtesy of J. Kozlowski

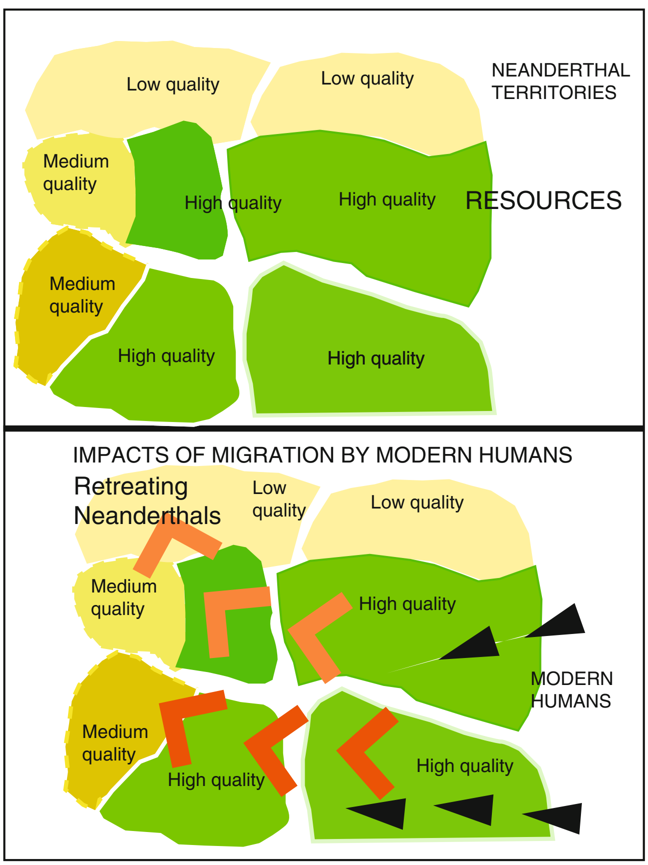


Fig. 2.5 A model of patchy resource distribution and the impacts of migrating modern humans

Szeletian" in Buran Kaya III (Marks and Monigal 2000). Thus the Eastern Szeletian culture is interpreted as demonstrating Neanderthal lithic technology influenced by interactions with modern humans occurred in a wide geographic distribution from Crimea, the middle and lower Don valley to the central and northern Urals (Chabai 2007 and references therein). Given the northern dispersals of the makers of the Streletskaya industry, I propose to interpret this prehistoric situation as reflecting the geographic retreat the Neanderthals under the pressures of the expanding modern humans (Fig. 2.4).

The Gorodtsovskaya culture (ca. 30/28–26 Ka) with its rich bone and ivory objects is seen as the product of modern human groups. A similar interpretation is suggested for the Spitsynskaya entity due to its dominant blade industry and the bone and ivory elements. Hence, the archaeological data from southeastern Europe supports the notion of non-violent encounters between the two populations. Anikovich and associates (2007) in a review of the Kostenki area suggested a model of acculturation resulting from steady interactions and possible interbreeding between modern humans and Neanderthals. They stress the validity of their observation by noting that on the Russian plain in general (including Kostenki) there are no real Middle Paleolithic sites. They describe their cultural observations of the studied assemblages as "symbiotic industries," meaning the outcome of constant meetings between the two populations.

2.6 Final Remarks

Resolving issues related to Neanderthals and modern humans required moving away from European terminology and the imposition of the Upper Paleolithic sequence of this continent. Scholars realized that regional sequences across Asia should be reconstructed on the basis of systematic excavations and properly dated contexts. However, we still do not have a comparable level of knowledge except perhaps in the Levant, particular areas within the landmass of Siberia, and the Japanese archipelago. But recent decades reveal fast accumulating information in other regions. Thus it is a fruitless effort to provide here a comprehensive summary. Suffice it to say from my viewpoint, that in every country that is being studied in detail we discover not only the local cultural characteristics but also commonalities or boundaries with other prehistoric entities in neighboring areas. For example, the overall phenomena of microblade industries from north China, Mongolia, Siberia, Korean peninsula, the Japanese archipelago, Alaska and a portion of the North American West Coast, could be identified with waves of migrations from a general "homeland" and/or secondary "homelands" mostly following a geographic trajectory from west to east. In some cases, if we take up the challenge, it allows us to have a more general understanding of past human history that determined what happened later during the Holocene.

In addition to the spatial distribution of Neanderthal and modern humans meta-populations and their history, the importance attributed in the RNMH project to the processes of teaching and learning and their impacts on the formation of lithic traditions we should continue to reveal the various operational sequences practiced during the Upper Pleistocene. In several schools of Archaeology experiments in replications and refitting are already conducted the more would improve our ability to carry out comparisons over long distances. However, we also need to try and move beyond the mere descriptions of the operational sequences into as yet poorly studied domains.

The first is the realm of real people by forming hypotheses that would compare the variability among the languages with our prehistoric data sets. The second would be to consider biological issues when two meta-populations interact and clash with each other. One of these subjects is the impact of modern humans on the spatial distribution of food resources when they enter the territories of the Neanderthals (Fig. 2.5). Reduction in the quality of food resources and their dispersed distribution would affect the retreating population. Modelers can calculate how long a certain population of the Neanderthals would survive a decrease in their Total Fertility Rate. A published essay (Sørensen 2011) demonstrates how within a few centuries for a small population would disappear due to constant reduction in the number of births as well as high infant mortality. He tests the model with the age distribution of fossils published by Trinkaus (1995). An unpublished experimental model done by the author indicated the same. Just a small fraction of 0.05 in the Total Fertility Rate would constantly decrease a population. Employing newly accumulated palaeoanthropological information concerning Neanderthals' demography should test these hypotheses. Hence, by testing various hypotheses that should take into account the successful range of interbreeding between these two populations, even if limited, we can come closer to reconstructing the history of recent humankind.

Acknowledgements This paper is based on my public lecture at the opening of the symposium and represents my personal views concerning the issues involved in the investigation of the complex interrelationships of "Neanderthals and Modern humans." I thank Takeru Akazawa and Yoshihiro Nishiaki for organizing the conference and the other participants in this meeting for their stimulating presentations. My views are based on many years of discussions with other colleagues during the excavations of Kebara, Qafzeh and Hayonim caves excavations as well as our joint fieldwork in Georgia and the Czech Republic. Needless to mention that I am the sole responsible for the shortcoming of this text.

References

Adler DS, Belfer-Cohen A, Bar-Yosef O (2006) Between a rock and hard place: Neanderthal-modern human interactions in the southern Caucasus. In: Conard NJ (ed) When Neanderthals and modern humans met. Tübingen Publications, Kerns, Rottenburg, pp 165–188

Adler DS, Bar-Yosef O, Belfer- Cohen A, Tushabramishvili N, Boaretto E, Mercier N, Valladas H, Rink WJ (2008) Dating the demise: Neandertal extinction and the establishment of modern humans in the southern Caucasus. J Hum Evol 55:817–833

Anikovich MV, Anisiutkin NK, Vishniatsky LB (2007) Uzlovye problemy perekhoda k verkhnemu paleolitu v Evrazii (Key problems of the Upper Palaeolithic transition in Eurasia). Nestor-istoria, St. Petersburg

Arensburg B, Belfer-Cohen A (1998) Sapiens and Neandertals: rethinking the Levantine Middle Paleolithic hominids. In: Akazawa T, Aoki K, Bar-Yosef O (eds) Neandertals and modern humans in western Asia. Plenum, New York, pp 311–322

Ashton NM, McNabb J, Lewis SG, Parfitt SA (1994) Contemporaneity of Clactonian and Acheulian flint industries at Barnham, Suffolk. Antiquity 68(260):585–589

Bailey SE, Hublin JJ (2006) Dental remains from the grotte du Renne at Arcy-sur-Cure (Yonne). J Hum Evol 50(5):485–508

Bar-Yosef O (1988) The date of South-West Asian Neandertals. In: Otte M (ed) L'Anatomie. L'Homme de Neandertal, vol 3. ERUAL, Liege, pp 31–38

Bar-Yosef O (1994) The contributions of Southwest Asia to the study of the origins of modern humans. In: Nitecki MH, Nitecki DV (eds) Origins of anatomically modern humans. Plenum, New-York and London, pp 23–66

Bar-Yosef O (1998) Chronology of the Middle Paleolithic of the Levant. In: Akazawa T, Aoki K, Bar-Yosef O (eds) Neandertals and modern humans in western Asia. Plenum, New-York, pp 39–56

Bar-Yosef O (2000) Late Middle and Early Upper Paleolithic in western Asia. In: Bar-Yosef O, Pilbeam D (eds) The geography of Neandertals and modern humans in Europe and the greater Mediterranean. American School of Prehistoric Research, Peabody Museum, Cambridge, pp 130–156

Bar-Yosef O (2002) The Upper Paleolithic revolution. Annu Rev Anthropol 31:363–393

Bar-Yosef O (2011) A geographic overview of Neanderthal-modern human encounters. In: Sept J, Pilbeam D (eds) Casting the net wide: papers in honor of Glynn Isaac and his approach to human origins research. Monographs of the American School of Prehistoric Research, Peabody Museum, Harvard University, Cambridge, pp 193–212

Bar-Yosef O, Belfer-Cohen B (1996) Another look at the Levantine Aurignacian. In: Montet-White A, Palma di Cesnola A (eds) Colloquium XI – the Late Aurignacian. Proceedings of the XIII conference of the international congress of Prehistoric and Protohistoric sciences, UISPP. A.B.A.C.O. Edizioni, Forlì, pp 139–150

Bar-Yosef O, Bordes J-G (2010) Who were the makers of the Chatelperronian. J Hum Evol 50:586–593

Bar-Yosef O, Kuhn S (1999) The big deal about blades: laminar technologies and human evolution. Am Anthropol 101(2):1–17

Bar-Yosef O, Van Peer P (2009) The chaïne opératoire approach in Middle Paleolithic archaeology. Curr Anthropol 50(1):103–131

Bar-Yosef O, Wang Y (2012) Paleolithic archaeology in China. Annu Rev Anthropol 41:319–335

Bar-Yosef O, Zilhao J (eds) (2006) Towards the definition of the Aurignacian. IPA, Lisbon

Belfer-Cohen A, Bar-Yosef O (1999) The Levantine Aurignacian: 60 years of research. In: Davies W, Charles R (eds) Dorothy Garrod and the progress of the Palaeolithic: studies in the prehistoric archaeology of the Near East and Europe. Oxbow Books, Oxford, pp 118–134

Boeda E, Geneste J-M, Meignen L (1990) Identification de chaïnes opératoire lithiques du Paleolithique Ancient et Moyen. Paleo 2:43–80

Boëda E (1995) Levallois: a volumetric construction, methods, a technique. In: Dibble HL, Bar-Yosef O (eds) The definition and interpretation of Levallois technology. Prehistory, Madison, pp 41–68

Bolus M (2003) The cultural context of the Aurignacian of the Swabian Jura. In: Zilhão J, d'Errico F (eds) The Chronology of the Aurignacian and of the transitional technocomplexes dating, stratigraphies, cultural implications. Instituto Português de Arqueollogia, Lisboa, pp 153–164

Bon F, Bodin P (2002) Analyse technologique du debitage Aurignacien. In: Schmider B (ed) L'Aurignacien de la grotte du Renne -les fouilles d'Andre Leroi-Gourhan a Arcy-sur-Cure (Yonne). CNRS Editions, Paris, pp 115–133

Bordes F (1961) Mousterian cultures in France. Science 134:803–810

Bourguignon L (1996) La conception de débitage Quina. Quaternaria Nova VI:149–166

Breuil H (1913) Les subdivisions du Paléolithique Supérieur et leur signification. Geneva. Conngrès International d'Anthropologie et d'Archéologie Préhistorique 1, Genève, pp 165–238

Burdukiewicz JM (2000) The backed biface assemblages of East Central Europe. In: Ronen A, Weinstein-Evron M (eds) Toward modern humans: the Yabrudian and Microquian, 400-50 k-years ago, vol 850, BAR International Series. Archaeopress, Oxford, pp 155–165

Cann LR, Stoneking M, Wilson AC (1987) Mitochondrial DNA and human evolution. Nature 325(1):31–39

Chabai V (2003) The chronological and industrial variability of the Middle to Upper Paleolithic transition in eastern Europe. In: Zilhão J, D'Errico F (eds) The chronology of the Aurignacian and of the transitional technocomplexes: dating, stratigraphies, cultural implications. Instituto Português de Arqueollogia, LISBOA, pp 71–88

Chabai VP (2007) The Middle Paleolithic and Upper Paleolithic in the northern Black Sea region. In: Yanko-Homback V et al (eds) The Black Sea flood question. Springer, New York, pp 279–296

Chabai VP, Monigal K (1999) The Middle Paleolithic of Western Crimea, vol 2. ERAUL87, Liège

Conard NJ (2006) Changing views of the relationship between Neanderthals and modern humans. In: Conard NJ (ed) When Neanderthals and modern humans met. Tübingen Publications, Kerns, Rottenburg, pp 5–20

Conard NJ, Fischer B (2000) Are there recognizable cultural entities in the German Middle Paleolithic. In: Ronen A, Weinstein-Evron M (eds) Toward modern humans: the Yabrudian and Microquian, 400-50 k-years ago, vol 850, BAR International Series. Archaeopress, Oxford, pp 7–24

Deacon HJ, Deacon J (1999) Human beginnings in South Africa: uncovering the secrets of the stone age. David Phillips Publishers and Altamira, Cape Town and Walnut Creek

Delagnes A, Rendu W (2011) Shifts in Neandertal mobility, technology and subsistence strategies in western France. J Archaeol Sci 38:1771–1783

Derevianko AP (2011) Three scenarios of the Middle to Upper Paleolithic transition: Scenario 2: the Middle to Upper Paleolithic transition in continental East Asia. Archaeol Ethnol Anthropol Eurasia 39(1):2–27

Derevianko AP, Markin SV (1995) The Mousterian of the Altai in the context of the Middle Paleolithic culture of Eurasia. In: Dibble HL, Bar-Yosef O (eds) The definition and interpretation of Levallois technology. Prehistory, Madison, pp 473–484

Derevianko AP, Shunkov MV (2002) Middle Paleolithic industries with foliate bifaces in Gorny Altai. Archaeol Ethnol Anthropol Eurasia 9(1):16–42

d'Errico F, Zilhão J, Julien M, Baffier D, Pelegrin J (1998) Neanderthal acculturation in western Europe? A critical review of the evidence and its interpretation. Curr Anthropol 39(Supplement):S1–S44

d'Errico F, Julien M, Liolios D, Vanhaeren M, Baffier D (2003) Many awls in our argument: bone tool manufacture and use in the Châtelperronian and Aurignacian levels of the Grotte du renne at Arcy-sur-Cure. In: Zilhão J, D'Errico F (eds) The chronology of the Aurignacian and of the transitional technocomplexes: dating, stratigraphies, cultural implications. Instituto Português de Arqueollogia, LISBOA, pp 247–272

Eren MI, Bradley B, Sampson CG (2011) Middle Paleolithic skill-level and the individual knapper: an experiment. Am Antiquity 76:229–251

Eren MI, Stephen J, Lycett SJ, Roos CI, Sampson G (2012) Toolstone constraints on knapping skill: Levallois reduction with two different raw materials. J Archaeol Sci 38:2731–2739

Gamble C, Davies W, Pettitt P, Richards M (2004) Climate change and evolving human diversity in Europe during the last glacial. Philos Trans R Soc Lond B 359:243–254

Gilman A (1984) Explaining the Upper Palaeolithic revolution. In: Springs E (ed) Marxist perspectives in archaeology. Cambridge University Press, Cambridge, pp 220–237

Goldberg P, Macphail RI (2006) Practical and theoretical geoarchaeology. Balckwell, Malden

Golovanova LV, Doronichev VB (2003) The Middle Paleolithic of the Caucasus. J World Prehist 17(1):71–140

Golovanova LV, Doronichev VB, Cleghorn NE (2010) The emergence of bone-working and ornamental art in the Caucasian Upper Paleolithic. Antiquity 84(324):299–320

Green RE, Krause J, Briggs AW, Maricic T, Stenzel U, Kircher M, Patterson N, Li H, Zhai W, Hsi-Yang Fritz M, Hansen NF, Durand EY, Malaspinas A-S, Jensen JD, Marques-Bonet T, Alkan C, Prüfer K, Meyer M, Burbano HA, Good JM, Schultz R, Aximu-Petri A, Butthof A, Höber B, Höffner B, Siegemund M, Weihmann A, Nusbaum C, Lander ES, Russ C, Novod N, Affourtit J, Egholm M, Verna C, Rudan P, Brajkovic D, Kucan Z, Gušic I, Doronichev VB, Golovanova LV, Lalueza-Fox C, de la Rasilla M, Fortea J, Rosas A, Schmitz RW, Johnson PLF, Eichler EE, Falush D, Birney E, Mullikin JC, Slatkin M, Nielsen R, Kelso J, Lachmann M, Reich D, Pääbo S (2010) A draft sequence of the Neandertal genome. Science 328:710–728

Habgood PJ, Franklin NR (2008) The revolution that didn't arrive: a review of Pleistocene Sahul. J Hum Evol 55:187–222

Henshilwood CS, Marean CW (2003) The origin of modern human behavior: critique of the models and their test implications. Curr Anthropol 44(5):1–53

Higham T, Jacob R, Julien M, David F, Basell L, Wood R, Davies W, Bronk Ramsey C (2010) Chronology of the grotte du Renne (France) and implications for the context of ornaments and human remains within the Châtelperronian. Proc Natl Acad Sci 107(47): 20234–20239

Hovers E (2006) Neandertals and modern humans in the Middle Palaeolithic of the Levant: what kind of interaction? In: Conard NJ (ed) When Neanderthals and modern humans met. Tübingen Publications, Kerns, Rottenburg, pp 65–85
Hovers E, Kuhn SL (eds) (2006) Transitions before the transition: evolution and stability in the Middle Paleolithic and Middle Stone Age. Springer, New York
Howells WW (1974) Neanderthals: names, hypothesis, and scientific method. Am Anthrpol 75:24–38
Hublin J, Roebroeks W (2009) Ebb and flow or regional extinction? On the character of Neanderthal occupation of northern environments. Comptes Rendus Palevol 8:503–509
Hublin J-J, Talamo S, Julien M, David M, Connet N, Bodu P, Vandermeersch P, Richards MP (2012) Radiocarbon dates from the grotte du Renne and Saint-Césaire support a Neandertal origin for the Châtelperronian. Proc Natl Acad Sci 109(46):18743–18748
Jacobs Z, Roberts RG, Galbraith RF, Deacon HJ, Grun R, Mackay A, Mitchell P, Ralf V, Wadley L (2008) Ages for the Middle Stone Age of Southern Africa: implications for human behavior and dispersal. Science 322:733–735
Jöris O (2006) Bifacially Backed Knifes (Keilmesser) in the Central European Middle Palaeolithic. In: Goren-Inbar N, Sharon G (eds) Axe age – Acheulian toolmaking from quarry to discard. Approaches to anthropological archaeology. Equinox, London, pp 287–310
Klein RG (2009) The human career: human biological and cultural origins, 23rd edn. University of Chicago Press, Chicago
Kozlowski JK (2000) The problem of cultural continuity between the Middle and the Upper Paleolithic in Central and Eastern Europe. In: Bar-Yosef O, Pilbeam D (eds) The geography of Neandertals and modern humans in Europe and the Greater Mediterranean. American School of Prehistoric Research, Peabody Museum, Cambridge, pp 77–105
Kozlowski JK (2004) Early Upper Paleolithic Levallois-derived industries in the Balkans and in the Middle Danube basin. Anthropol Intl J Sci Man XLII(3):263–280
Kozlowski JK, Otte M (2000) The formation of the Aurignacian in Europe. J Anthropol Res 56:513–534
Krause J, Orlando L, Serre D, Viola B, Prüfer K, Richards MP, Hublin J-J, Hanni C, Derevianko AP, Paabo S (2007) Neanderthals in central Asia and Siberia. Nature 449:1–3
Kuhn SL (2003) In what sense is the Levantine initial Upper Paleolithic a "transitional" industry? In: Zilhão J, D'Errico F (eds) The chronology of the Aurignacian and of the transitional technocomplexes: dating, stratigraphies, cultural implications. Instituto Português de Arqueollogia, LISBOA, pp 61–70
Kuhn SL, Brantingham PJ, Kerry KW (2004) The Early Paleolithic and the origins of modern human behavior. In: Brantingham PJ, Kuhn SL, Kerry KW (eds) The early Upper Paleolithic beyond western Europe. University of California Press, Berkeley, pp 242–248
Lemonnier P (1976) La description des chaînes opératoires: contribution à l'analyse des systèmes techniques. Techniques et culture 1:100–151
Lemonnier P (1992) Elements for an anthropology of technology. Anthropological papers, Museum of Anthropology, 88. University of Michigan, Ann Arbor
Lévêque F, Backer AM, Guilbaud M (eds) (1993) Context of a late Neanderthal. Prehistory, Madison
Lewis-Williams JD (1997) Harnessing the brain: vision and shamanism in Upper Paleolithic western Europe. In: Conkey MW, Soffer O, Stratmann D, Jablonski NG (eds) Beyond art: Pleistocene image and symbol. Memoirs of the California Academy of Sciences. California Academy of Sciences, San Francisco, pp 321–342, 23, N. G. Jablonski, general editor
Lowe J, Barton N, Blockleya S, Bronk Ramseyc CVL, Cullen VL, Davies W, Gamble C, Grant K, Hardiman M, Housley R, Lane CS, Lee S, Lewisf M, MacLeod A, Menzies M, Müller W, Pollard M, Price C, Roberts AP, Rohling EJ, Satow C, Smith VC, Stringer CB, Tomlinson EL, White D, Albert A, Arienzo I, Barker B, XBoric B, Carandente A, Civetta L, Ferrier C, Luc Guadelli J-L, Karkanas P, Koumouzelis M, Müller UC, Orsi G, Pross J, Rosi M, Shalamanov-Korobar L, Sirakov N, Tzedakis PC (2012) Volcanic ash layers illuminate the resilience of Neanderthals and early modern humans to natural hazards. Proc Natl Acad Sci 109(34):13532–13537
Marks AE, Chabai VP (2006) Stasis and change during the Crimean Middle Paleolithic. In: Hovers E, Kuhn SL (eds) Transitions before the transition: evolution and stability in the Middle Paleolithic and Middle Stone Age. Springer, New York, pp 121–136
Marks AE, Monigal K (2000) The Middle to Upper Palaeolithic interface at Buran-Kaya-III, Eastern Crimea. In: Orschiedt J, Weniger G-C (eds) Neanderthals and modern humans – discussing the transition: Central and Eastern Europe from 50.000-30.000 B.P. Neanderthal Museum, Mettman, pp 212–226
McBrearty S, Brooks AS (2000) The revolution that wasn't: a new interpretation of the origin of modern human behavior. J Hum Evol 39(5):453–563
Meignen L (1998a) Hayonim cave lithic assemblages in the context of the near Eastern Middle Paleolithic: a preliminary report. In: Akazawa T, Aoki K, Bar-Yosef O (eds) Neandertals and modern humans in western Asia. Plenum, New York, pp 165–180
Meignen L (1998b) Le Paléolithique moyen au Levant sud et central: que nous apprennent les données récentes? In: Otte M (ed) Préhistoire d'Anatolie: Genèse de deux mondes. Actes du colloque international. Liège, 28 avril - 3 mai 1997. ERAUL 85, Liège, pp 685–708
Meignen L, Delangnes A, Bourguinon L (2009) Patterns of lithic material procurement and transformation during the Middle Paleolithic in western Europe. In: Adams B, Blades BS (eds) Lithic materials and Paleolithic societies. Blackwell, New York, pp 15–24
Qu T, Bar-Yosef O, Wang Y, Wu X (2012) The Chinese Upper Paleolithic: geography, chronology and typo-technology. J Archaeol Res 15(1):1–73
Rahmani N (2004) Technological and cultural change among the last hunther-gatherers of the Maghreb: the Caspian (10,000-6000 B.P.). J World Prehist 18(1):57–105
Reich D, Patterson N, Kircher M, Delfin F, Nandineni MR, Pugach I, Min-Shan KA, Ko Y-C, Jinam TA, Phipps ME, Saitou N, Wollstein A, Kayser M, Pääbo S, Stoneking M (2011) Denisova admixture and the first modern human dispersals into southeast Asia and Oceania. Am J Hum Genet 89:1–13
Ronen A (1995) The Levallois method as cultural constraint. In: Dibble HL, Bar-Yosef O (eds) The definition and interpretation of Levallois technology. Prehistory, Madison, pp 293–304
Shea JJ (2003) Neandertals, competition, and the origin of modern human behavior in the Levant. Evol Anthropol 13:173–187
Sørensen B (2011) Demography and the extinction of European Neanderthals. J Anthropol Archaeol 30:17–29
Soressi M (2002) Le Moustérien de tradition acheuléenne du sud-ouest de la France. Ph.D dissertation, L'Université Bordeaux
Soressi M, Hays MA (2003) Manufacture, transport, adn use of Mousterian bifaces: a case study from the Périgord (France). In: Soressi M, Dibble HL (eds) Multiple approaches to the study of bifacial technologies. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia, pp 125–148
Svoboda JA (2005) The Neandertal extinction in eastern Central Europe. Quatern Intl 137:69–76
Teyssandier N (2008) Revolution or evolution: the emergence of the Upper Paleolithic in Europe. World Archaeol 40(4):493–519
Thoma A (1965) The definition of the Neanderthals and the position of the fossil men of Palestine. Yearb Phys Anthropol 13:122–145
Trinkaus E (1995) Neanderthal mortality patterns. J Archaeol Sci 22: 121–142
Trinkaus E (2007) European early modern humans and the fate of the Neandertals. Proc Natl Acad Sci U S A 104(18):7367–7372

Villa P, Soriano S, Teyssandier N, Wurz S (2010) The Howiesons Poort and MSA III at Klasies River main site, Cave 1A. J Archaeol Sci 37(3):630–655

Vishnyatsky LB (2005) How many core areas? the "Upper Paleolithic revolustion" in an east Eurasian perspective. J Israel Prehist Soc 35:143–158

Wadley L (2001) What is cultural modernity? A general view and a South African perspective from Rose Cottage Cave. Cam Archaeol J 11(2):201–221

Wadley L (2008) The Howieson's poort industry of Sibudu Cave. South African Archaeol Soc Goodwin Series 10:122–132

Wolf ER (1982) Europe and the people without history. University of California Press, Berkeley

Zilhão J, D'Errico F (eds) (2003) The chronology of the Aurignacian and of the transitional technocomplexes: dating, stratigraphies, cultural implications. Instituto Português de Arqueollogia, LISBOA

Zilhao J, d'Errico F, Bordes J-G, Lenoble A, Texier J-P, Rigaud J-P (2006) Analysis of aurignacian interstratification at the Chatelperronian-type site and implications for the behavioral modernity of neandertals. Proc Natl Acad Sci 103(33):12643–12648

Zilhao J, Trinkaus E, Constantin S, Milota S, Gherase M, Saecina L, Rougier H, Quilès J, Rodrigo R (2007) The Pestera cu Oase people, Europe's earliest modern humans. In: Mellars P, Boyle K, Bar-Yosef O, Stringer C (eds) Rethinking the human revolution. McDonald Institute for Archaeological Research. Cambridge University Press, Cambridge, pp 249–262

Neandertal-Modern Human Contact in Western Eurasia: Issues of Dating, Taxonomy, and Cultural Associations

3

João Zilhão

Abstract

Supporting Assimilation views of Neandertal/modern human interaction, chronostratigraphic reasoning indicates that the “transitional” industries of Europe predate modern human immigration, in agreement with their association with Neandertals in the Châtelperronian at the Grotte du Renne and St.-Césaire. Supporting the Neandertals' species separateness and less developed cognition, those industries are alternatively claimed to relate to pioneer groups of modern humans; the latter would have been the true makers of the precocious instances of symbolic material culture that, under Assimilation, are assigned to the Neandertals. However, the taxonomy of the Kent's Cavern and Grotta del Cavallo dental remains is uncertain, and their poor stratigraphic context precludes dating by association. The opposite happens at the Grotte du Renne, whose stratigraphic integrity is corroborated by both taphonomy and dating. Not questioning that the Early Ahmarian is a cultural proxy for modern humans and a source for the Protoaurignacian of Europe, its claimed emergence ~46–49 ka ago at Kebara reflects the dating of Middle Paleolithic charcoal—to be expected, because the Early Ahmarian units at the back of the cave are made up of reworked Middle Paleolithic sediments derived from the entrance. The dating of inherited material also explains the old results for the Aurignacian of Willendorf II and Geissenklösterle. At the latter, the dates on anthropically modified samples of the hunted taxa (reindeer and horse) place its Aurignacian occupations in the same time range as elsewhere in Europe, after ~40 ka ago. The hypothesis that Neandertal/modern human contact in Europe resulted in a process of assimilation in connection with the spread of the Protoaurignacian ~41.5 ka ago remains unfalsified.

Keywords

Aurignacian • Bayesian modeling • Châtelperronian • Chronostratigraphy • Radiocarbon

3.1 Introduction

During the last two decades of the twentieth century, the debate concerning the emergence of European modern humans and the fate of the Neandertals revolved around the polar alternatives of “Multiregionalism” and “Recent African Origin.” In their original formulations, where Multiregionalism saw modern humans as principally locally evolving from ancestral populations of “archaics,” Recent

J. Zilhão (✉)
Departament de Prehistòria, Història Antiga i Arqueologia, University of Barcelona/ICREA, C/Montalegre 6, 08001 Barcelona, Spain
e-mail: joao.zilhao@ub.edu

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_3,

African Origin defined them as a new species originating at least 150,000 years ago in Africa, from where the rest of the world was eventually colonized, with Eurasia's aboriginal humans, especially the Neandertals, becoming extinct without descent in the process.

A minority position, "Assimilation," accepted recent Out-of-Africa migration and/or genetic diffusion but viewed Neandertals as a geographical variant of *Homo sapiens*, not as a different biological species. In this view, the disappearance of Eurasian archaics from the paleontological record after about 40,000 years ago would have been caused by loss of isolation and ensuing integration with the wider human gene pool, that is, by demographic and/or natural selection processes operating in a context of significant population admixture. Human Paleontology (Trinkaus 2007), Genetics (Hawks 2012) and Archeology (Zilhão 2006a, 2011, 2012) now concur in indicating that such Assimilation models best match the empirical data concerning the replacement of Neandertals by modern humans accumulated over the last 15 years of research developments, briefly summarized below.

Direct dating of the fossils that were once thought to represent Europe's earliest modern humans and, by their lack of archaic features, supported replacement-with-no-admixture of the Neandertals, showed they were all of a significantly younger age (recent Holocene for some), as the Vogelherd case (Conard et al. 2004) best illustrates. Conversely, all of the newly discovered or restudied fossils dated to the time of the Neandertal-to-modern human transition in Europe or shortly thereafter were shown to present archaic if not Neandertal-diagnostic features (e.g., the Lagar Velho and Oase fossils; Duarte et al. 1999; Trinkaus 2007; Trinkaus et al. 2013). These morphological mosaics indicated admixture at the time of contact, and the Neandertal genome project (Green et al. 2010) eventually produced corroborating evidence—namely, that 1–4 % of the genome of extant Eurasians is of Neandertal origin.

At the same time, archeological research provided evidence that, in the behavioral realm, late Neandertals had been as "modern" as their African contemporaries. While Recent African Origin views interpreted many innovations of the European Upper Paleolithic as a "Human Revolution" (Mellars and Stringer 1989) triggered by the immigration of modern humans, the new evidence credited many of those innovations to the Neandertals and showed that some had first appeared in the preceding Middle Paleolithic. Among the latter is the use in body ornamentation of painted/perforated marine shells, large raptor feathers, and mineral pigments modified as crayons or processed for the preparation of complex cosmetic recipes (Soressi and d'Errico 2007; Zilhão et al. 2010a; Peresani et al. 2011; Morin and Laroulandie 2012; Finlayson et al. 2012). It is also quite possible that Neandertals were the makers of the earliest known cave art, as suggested by the minimum age of 41.4 ± 0.6 ka (95.4 % probability interval) provided by U-series dating of calcite accretions covering geometric signs and hand stencils at the Spanish site of El Castillo (Cantabria; Pike et al. 2012).

The paleontological and genetics evidence vindicates Holliday's (2006) prediction that no biological barriers to productive interbreeding could have existed between Neandertals and their African contemporaries; as he pointed out, if human history is seen under the perspective of general mammalian evolutionary patterns, the amount of time elapsed since separation of the two lineages from their common ancestor becomes simply insufficient, and this by a factor of about ten, for intersterility to have arisen. The overall similarity in human culture between Eurasia and Africa implied by the symbolism-related features apparent in the archeological record of both continents after 100,000 years ago also carries admixture-related implications; namely, that the existence of cognitive or cultural barriers to interbreeding can be removed from the range of mechanisms putatively preventing its occurrence.

The corollary of these developments is that the Assimilation view of modern human/Neandertal interaction ought to be considered the null hypothesis of modern human origins in Eurasia (and, therefore, that the burden of proof lies on those who think otherwise). A strand of scientific opinion maintains, however, that the evidence for Assimilation is equivocal. Namely, there are two major and closely inter-related tenets of this view that critics have directly or indirectly challenged: the association of Neandertals with the Châtelperronian and coeval, "transitional" cultures of the Early Upper Paleolithic; and the view that the Protoaurignacian represents the earliest archeological manifestation that conceivably can be related to modern humans in Europe.

Although based on different aspects of the empirical record and following different lines of reasoning, such challenges to Assimilation share the contention that problems with dating have so far obscured the fact that the instances of precocious symbolism seen in the archeological record of Europe, those that apparently pre-date modern human immigration, are in deed modern human-, not Neandertal-related. In some instances, the case is made that the direct dates on Neandertal fossils placing them in the time range of the first appearance of symbolic artifacts in the European record are too young (or that the association of the fossils with stratigraphic contexts of such age is spurious). In other instances, the case is made for modern humans, as represented by their fossils or putative archeological proxies, to have arrived in western Eurasia significantly earlier than hitherto thought, which would imply that Europe's oldest symbolic material culture is theirs, not the Neandertals'.

In the following, I will examine and discuss such claims. I have no intention of being exhaustive, and will therefore focus on those cases that have attracted more attention or whose implications are of more far-reaching consequence. The discussion will proceed on a case by case basis, examining the arguments and assessing their strength in terms of the empirical observations that support them. I will then wrap up with a conclusion that sets the debate on western Eurasia's Middle-to-Upper and Neandertal-to-modern human transitions in the broader perspective of patterns of cultural change during the last 150,000 years.

Throughout, the following conventions will be followed: solar calendar dates as well as those derived from TL (Thermoluminescence), OSL (Optically Stimulated Luminescence) and U-series techniques will be expressed in years or thousands of years (ka) ago; dates derived from Radiocarbon will be expressed in years or thousands of years (ka) "^{14}C BP," and, when calibrated, denoted as "cal BP," in which case they will be given either as approximate ages (e.g., ~40 ka cal BP) or as 95.4 % probability intervals. When dates are compared to assess whether they are statistically distinct or the same, the tool used is the sample significance test (Case 1) of Ward and Wilson (1978), carried out with Calib 6.1. (Stuiver and Reimer 1993).

3.2 Axiomatic Principles and Chronological Framework

My null chronological hypothesis is a model of the Middle-to-Upper and Neandertal-to-modern human transitions in western Eurasia first proposed by d'Errico et al. (1998) and Zilhão and d'Errico (1999), and further elaborated in Zilhão and d'Errico (2003), Zilhão (2006a, 2007, 2011) and Banks et al. (2013). This model can be summarized as follows:

(a) The Châtelperronian, Uluzzian, Altmühlian, Bohunician, Szeletian and Bachokirian underlie the earliest Aurignacian across the whole of their shared geographic range, and, therefore, they must predate the Aurignacian in each of their particular areas of occurrence.

(b) The recognized subdivisions of the Aurignacian have chronological value and are not functional or cultural variants that could have been in coexistence at given points of the technocomplex's time range or even throughout its entire duration.

(c) A Protoaurignacian phase preceded the classic Aurignacian I with split-based points.

(d) This framework is replicated by dating provided that one rejects radiometric results that fail to pass a number of specified quality criteria.

(e) When only reliable radiocarbon results are considered, the boundary between the Protoaurignacian and the preceding "transitional" industries falls in the millennium centered around 36.5 ka ^{14}C BP (i.e., ~41.5 ka cal BP), with Bayesian modeling constraining the Protoaurignacian time range to the 39.9–41.5 ka cal BP interval.

(f) In Europe, all directly dated, or reliably associated diagnostic fossil remains of modern humans, are, at the earliest, of Protoaurignacian age, implying Neandertal authorship of the archeological record formed with anteriority, as otherwise corroborated by the Neandertal-diagnostic remains found in stratigraphic association with the Châtelperronian or directly dated to the corresponding chronostratigraphic slot.

This model is based on two key axioms. The first axiom is that the technocomplexes of the Upper Paleolithic are valid culture-stratigraphic units. The low resolution of stratigraphic sequences and the standard deviations of individual dating results (compounded, where the radiocarbon method is concerned, with the uncertainty added by calibration) mean that the smallest units of time we can work with in the interval of concern here (between 30,000 and 50,000 years ago) are in the range of five centuries to a millennium, at the very best. However, in the absence of major barriers to diffusion, advantageous innovations spread among hunter-gatherers much faster than that because of the open, exogamic nature of their social networks. Therefore, even though, obviously, a given innovation will have arisen first in a given place, it is almost inevitable that, in this period, its emergence and spread will become observationally conflated in a single process, one that will appear to us as an "event" taking place in "simultaneous" fashion over extensive areas. As, due to such inherent properties of the data it works with, Paleolithic Archeology is not about the short-term processes that occur in human lifetime scales (the study of which requires written or oral history records) but about the "steady state" of cultural/adaptive systems and their long-term change through time, this apparent "limitation" is, in fact, an "advantage" (Binford 1983).

When the comparison between two geographically connected regional sequences shows that the change from a given, shared steady state led to a new, different steady state that is also common to them, it is therefore axiomatic to Paleolithic Archeology that such a change must have occurred "simultaneously" in both regions. Such culture-stratigraphic reasoning has provided the backbone of Paleolithic chronologies for more than a century. The advent of radiometric dating made it possible to refine such chronologies to a certain extent, especially where the Upper Paleolithic is concerned. It also generated a number of apparent contradictions with traditional schemes, but such contradictions resulted from ambiguity in definitions and/or errors in the dating process (cf. Zilhão and d'Errico 1999); as the last 15 years of research have demonstrated, the chronological predictions derived from culture-stratigraphic arguments were indeed the correct ones, with advancements in dating technique and methodology (cf. Higham 2011) eventually producing results that agreed with culture-stratigraphic expectations.

The second axiom is that, regardless of which taxonomic status best describes their separateness (e.g., species or subspecies), Neandertals and modern humans are populations whose differentiation from a common ancestor was caused by geographic isolation. The possibility of long-term sympatry between the two phyla was envisaged by some in the past (e.g., Vallois 1949), but it has since become clear that no Neandertal fossils exist in the late Middle and early Upper Pleistocene record of northern Africa and, conversely, that no modern human fossils exist in the coeval European record. Even though, for particular space/time slots, the lack of fossil finds means that no direct association with the corresponding cultural record exists, an allopatric understanding of Neandertals and modern humans carries a straightforward implication—that, prior to the time when the replacement of the former by the latter is documented in the paleontological record of Europe, the continent was inhabited by Neandertals only, with the attendant corollary for issues of authorship.

3.3 Late Neandertals: How Late, and What Associations?

In Iberian regions situated to the south of the Ebro River drainage, Neandertals and the Mousterian arguably persisted for several millennia beyond their documented time range elsewhere in Europe (Zilhão et al. 2010a, b; Hoffmann et al. 2013). It is also possible that a similar but shorter persistence pattern, albeit in an Upper Paleolithic context (the Lincombian/Ranisian/Jerzmanowician), not a Middle Paleolithic one, underpins the direct dating to the ~41.0–41.5 ka cal BP interval of the two adult individuals from Spy (Semal et al. 2009; Flas 2011). In both cases, such late Neandertal occurrences concern areas located outside the geographic range of the Protoaurignacian, while the directly dated Oase fossils, although lacking an immediate archeological context, come from a region where a coeval Protoaurignacian is well documented (Hahn 1977; Zilhão 2006a; Teyssandier 2008).

Still, as no human remains have so far been found in direct association with the Protoaurignacian, it would be legitimate to infer from the Spy dates that no one-to-one correspondence exists between this culture and human paleontological taxa—i.e., that Neandertals and modern humans could both have been involved in the making of the Protoaurignacian. Two other conceivable implications of that evidence would, however, be clearly fallacious:

(a) The first would be that, if Neandertals made the Châtelperronian, we can then infer from their persistence in regions both to the south and to the north that the French Châtelperronian could have been as late as the Lincombian of Belgium or the Late Mousterian of Iberia. However, the Châtelperronian stratigraphically precedes the Protoaurignacian, and the geographic range of the Châtelperronian is totally encompassed within that of the Protoaurignacian. Therefore, envisaging a persistence of the Châtelperronian alongside the Protoaurignacian, with both falling in the same time interval but occupying different regions, amounts to positing an archeological impossibility, a point whose full significance will become apparent below.

(b) The second would be that the late dates for the last of the Belgian and Iberian Neandertals could simply be a byproduct of incomplete sample decontamination, leading to results that are too young (Pinhasi et al. 2011; Wood et al. 2013); therefore, such could well be also the case with the dates for Neandertal remains that place them, either directly or by stratigraphic association, in the time range of the Châtelperronian and coeval technocomplexes. However, the dates supporting the Neandertal/Châtelperronian link are, firstly, much older than those supporting late Neandertal persistence in Belgium and Iberia, and, secondly, fall in a period when Europe is entirely lacking in diagnostic modern human fossils; consequently, it is clear that no logical connection exists between the two propositions. If the last of the Neandertals are going to be made significantly older than indicated by the current dating record, it can only be on the basis of a robust case built on the chemistry of the dated samples and/or on issues of inconsistency with the stratigraphic context.

The above explains why, for the purposes of this paper, it is sufficient to restrict the discussion of late Neandertal dating and cultural associations to the key French occurrences. Such key occurrences are the Grotte du Renne, at Arcy-sur-Cure (Yonne), and the rock-shelter of La Roche-à-Pierrot, at St.-Césaire (Charente-Maritime). The first site is where Leroi-Gourhan (1958) originally proposed (on the basis of archaic features perceived in the dental remains from the corresponding levels of the site) that the Châtelperronian could have been made by the Neandertals. Fifteen years later, this notion would be boosted by the discovery at the second site, in a Châtelperronian context, of a diagnostic partial skeleton (Lévêque and Vandermeersch 1980). If current age estimates for these two occurrences are indeed too young, then the speculation explicitly or implicitly entertained by recent critics of Assimilation—that, in the period between 40,000 and 45,000 years ago, modern humans were the true makers of the archeology of most if not all of Europe—becomes an empirically viable hypothesis.

3.3.1 St.-Césaire

La Roche-à-Pierrot features a stratigraphic sequence spanning the Middle-to-Upper Paleolithic transition, one where, as originally described, Châtelperronian levels EJOPsup and EJOPinf are sandwiched between two ensembles of Aurignacian (levels EJJ to EJOsup) and Mousterian (levels

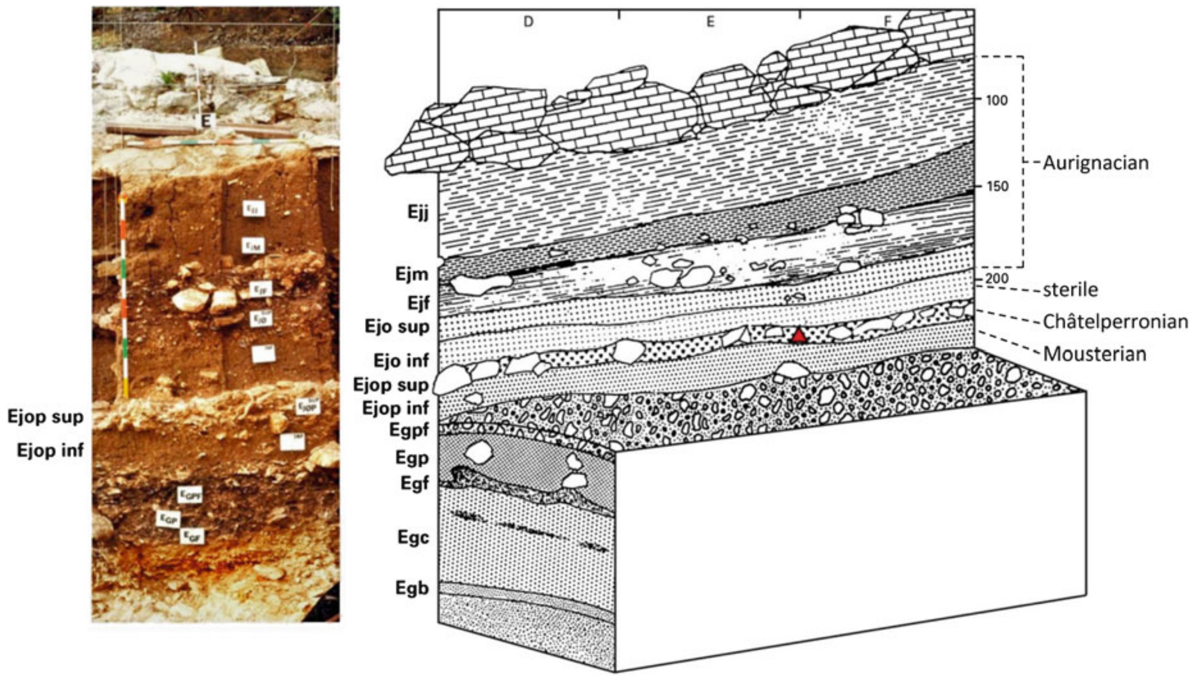


Fig. 3.1 Saint-Césaire. *Left*: Photograph of the stratification with indication of layers Ejop sup and Ejop inf; the scale bar is 1 m. *Right*: Schematic stratigraphy of the site with indication of the main units and of the position of the partial Neandertal skeleton (represented by the *red triangle*); elevations are in cm. From Hublin et al. (2012a: Fig. S2), modified

EGBinf to EGPF) deposits (Morin et al. 2005) (Fig. 3.1). The partial skeleton, interpreted as a secondary burial, was found exposed, and partly eroded, at the surface of EJOPsup; removed from the site as a block, it was subsequently excavated in the laboratory.

Recent re-analyses (Bar-Yosef and Bordes 2010; Bordes and Teyssandier 2011; Soressi 2011), however, raise a number of questions concerning the association between the skeleton and the Châtelperronian. Namely, they show that the lithic assemblage of EJOPinf is in fact Mousterian, while EJOPsup contains both Châtelperronian and Middle Paleolithic components, the latter displaying a distinct preservation condition and representing more than two thirds of the level's retouched tools. In addition, it is argued that no detailed description of the stratigraphy observed during the laboratory excavation of the block has been published, making it difficult to assess whether an intentional burial pit truly existed.

In this situation, alternative interpretations of the skeleton's associations are legitimate. For instance, the Mousterian component of EJOPsup could stand for the occurrence of an episode of debris flow or solifluction through which the level would have been originally laid down; the Châtelperronian component would have accumulated at a later time on the surface of this redeposited context, the palimpsest in existence at the time of excavation resulting from the action of penecontemporaneous natural and anthropogenic factors. In such a scenario, the Neandertal remains could represent a Mousterian burial displaced by (and partly destroyed in) the process.

Based on the reported lack of stones in the immediate context of the skeleton, in contrast with their abundance elsewhere in EJOPsup, one might interpose, however, that a burial pit indeed existed (Vandermeersch 1993). In that case, the site formation scenario above would imply that the pit post-dated the redeposition event responsible for the level's Middle Paleolithic artifact component and, therefore, that the Neandertal skeleton could only be of a Châtelperronian or later (i.e., in this case, given stratigraphy, Aurignacian) age.

The direct radiocarbon dating of the skeleton to 36,200 ± 750 ^{14}C BP (OxA-18099; Hublin et al. 2012a, that is, to 39.6–42.5 ka cal BP, has clarified the picture in at least one way: under the assumption that the result is accurate, the dating unambiguously rejects the hypothesis that the St.-Césaire Neandertal is associated with the Mousterian component of EJOPsup. However, since the age range obtained overlaps the boundary between the chronostratigraphic time slots of the Châtelperronian and the Protoaurignacian in France, the dating does not reject that the skeleton relates to the latter instead of the former.

Based on the stratigraphic configurations observed at the time of excavation, and bearing in mind that the relevant levels (EJOPsup and EJOsup) are separated by the >10 cm-thick sterile level EJOinf, a Protoaurignacian connection is, however, unlikely, and this for two reasons. Firstly, if a pit had been excavated from EJOsup deep into EJOP, then it should have left a readily apparent scar in EJOinf, but none was observed. Secondly, such a pit would in that case post-date the formation of both EJOinf and EJOPsup and, therefore, the partial exposure of the skeleton at the surface of EJOPsup could no longer be related to the latter's clearly erosional upper boundary.

Thirty-five years after the discovery, attribution of the St.-Césaire skeleton to the Châtelperronian remains, therefore, the parsimonious reading of the evidence.

3.3.2 Grotte du Renne

The Grotte du Renne features a Châtelperronian sequence (levels VIII, IX and X) sandwiched between Mousterian (levels XI-XIV) and Protoaurignacian (level VII) deposits, the latter in turn overlain by Aurignacian and Gravettian levels. The Châtelperronian yielded a juvenile temporal bone and 29 teeth of undisputed Neandertal affinities (Hublin et al. 1996, 2012a; Bailey and Hublin 2006), as well as 39 objects of personal ornamentation, 1,615 pigment chunks (weighing a total of 17 kg, and mostly red ochre), and 139 worked bone items of a diverse typology (mostly awls) (Caron et al. 2011; Fig. 3.2). In the framework of Recent African Origin, this association posed an obvious problem. It is therefore unsurprising that supporters have insistently tried to explain it away, with the principal suggestions to that effect having been the following:

(a) The association is genuine, but the presence of symbolic artifacts in these levels is incidental, resulting from curiosity-driven collection by Neandertals of items discarded by modern humans living nearby, from Neandertal "imitation without understanding" of such modern human crafts, or from trade or exchange.

(b) The association is an artifact of post-depositional disturbance, with the Châtelperronian having been made by Neandertals and the apparently associated symbolic artifacts having been downwardly displaced from the overlying Aurignacian.

(c) The association is an artifact of post-depositional disturbance, with the Châtelperronian having been made by modern humans and the apparently associated Neandertal remains having been upwardly displaced from the underlying Mousterian.

The first hypothesis, otherwise known as the "Acculturation" model of the Châtelperronian (Mellars 1999; Hublin 2000; Gravina et al. 2005; Mellars et al. 2007; Mellars and Gravina 2008), is overtly inconsistent with the empirical evidence, as highlighted by d'Errico et al. (1998), Zilhão and d'Errico (1999), and Zilhão et al. (2006, 2008a, b). Namely, the byproducts of bone tool and personal ornament production recovered alongside the finished objects refute notions of acquisition via trading or scavenging of abandoned modern human sites, while the differences in blank choice, technology and typology counter imitation. In addition, chronostratigrapy shows that the Châtelperronian precedes the Aurignacian, the putative interstratification of Châtelperronian and Aurignacian levels at the sites of Le Piage, Roc-de-Combe and Grotte des Fées representing in fact excavation error and post-depositional disturbance or mixing. In short, since, at the time, there were no modern humans around to trade with or imitate, Acculturation is an empirically invalid explanation of the Grotte du Renne record.

Moreover, as discussed at greater length elsewhere (Zilhão 2007), at the time the Châtelperronian emerged in France, Southwest Asia was, overland, the closest place where a modern human presence is conceivable; therefore, if the Grotte du Renne's Châtelperronian resulted from long distance acculturation, the same sort of process should be apparent in the intervening geography, which is not the case. In addition, the ornamental material in use at that time in the Levant consists entirely of marine shells, mostly *Nassarius* and similar small-sized species recovered in some of the region's Initial Upper Paleolithic (IUP) or Emiran contexts (Kuhn et al. 2001). Even under the assumption that these technocomplexes are associated with modern humans, one can hardly see how their use of such beadwork material would have prompted Neandertals living thousands of kilometers away to start piercing the teeth of fox and other animals to use as neck pendants. Over such large distances, the only "influence" that could have been exerted is that concerning the notion of "personal ornamentation" itself. However, in western Europe, Neandertal body painting and personal ornamentation have Middle Paleolithic beginnings and predate both the IUP/Emiran and the Châtelperronian by thousands of years (Soressi and d'Errico 2007; Zilhão et al. 2010a; Peresani et al. 2011; Morin and Laroulandie 2012; Finlayson et al. 2012).

The second hypothesis, originally proposed by Taborin (1998, 2002) and White (2001, 2002), not only is equally unable to explain the techno-typological distinction between the Grotte du Renne's Châtelperronian productions and those from the Aurignacian, it is also inconsistent with the vertical distribution of the finds across the stratigraphic sequence of the site. In fact, contra what one would expect under such a hypothesis, Protoaurignacian level VII yielded only 8 ornaments, while 39 were found in the Châtelperronian sequence and, of these, three quarters came not from the level immediately underlying the Protoaurignacian, level VIII, but from the deepest one, level X (Zilhão 2006a, 2007, 2011). A similar objection applies to the third hypothesis, originally proposed by Bar-Yosef (2006) and Bar-Yosef and Bordes (2010), as, conversely, of the 34 Neandertal teeth found at the Grotte du Renne, three came from basal Mousterian level XIV, 29 from the Châtelperronian, and only two from the immediately underlying Mousterian levels XI and XII.

Until the late 1990s, attempts at radiocarbon dating the Grotte du Renne sequence yielded results for the Châtelperronian falling for the most part in the 32–34 ka

Levels	Ornaments	Pigments	Worked bone	Neandertal teeth	Dufour bladelets	Châtelperron points	Levallois flakes	Unretouched bladelets	Convergent sidescraprers
VII	8	39	70	0	287	1	0	2800	0
VIII	8	146	27	1	0	29	0	0	2
IX	2	286	17	3	0	67	0	0	28
X	29	1183	139	25	0	284	0	0	105
XI	0	5	1	1	0	2	9	0	4
XII	0	4	1	1	0	0	14	0	2
XIII	0	0	0	0	0	0	3	0	1
XIV	0	0	0	3	0	0	0	0	2

Fig. 3.2 The symbolic material culture of the Grotte du Renne Châtelperronian. *Above*: Personal ornaments made of perforated and grooved teeth (*1–6*, *11*), bones (*7–8*, *10*), and a fossil (*9*); *red* (*12–14*) and *black* (*15–16*) colorants bearing facets produced by grinding; bone awls (*17–23*). *Below*: Stratigraphic distribution of the key finds made in the site's Mousterian (levels XI–XIV), Châtelperronian (levels VIII–X) and Protoaurignacian (level VII) deposits. From Caron et al. (2011), modified

^{14}C BP age range (David et al. 2001), supporting the interstratificaton arguments for long-term contemporaneity with the Aurignacian and thereby strengthening Acculturation views of the evidence. The numerous inconsistencies in the dating corpus, however, indicated that those results, obtained on associated animal bone samples, were likely to be minimum ages only, while detailed analysis of the stone tool assemblage in level VII eventually allowed its assignation to the Protoaurignacian (Bon 2002; Bon and Bodu 2002). The recognition that this facies was of chronological rather than geographic or cultural significance implied in turn that levels VIII-X of the Grotte du Renne had to predate ~36.5 ka ^{14}C BP and, therefore, that most if not all of the radiocarbon dates for the site had to be rejected (Zilhão and d'Errico 2003).

Recent redating of the sequence at the Oxford Radiocarbon Accelerator Unit (ORAU) using samples treated with the more robust ultrafiltration protocol ameliorated the situation considerably, but some problems of stratigraphic inconsistency remained nonetheless (Higham et al. 2010, 2011a, b). These anomalies prompted a revival of the notion that the site had undergone major post-depositional disturbance, thereby providing ammunition to the view that the presence of symbolic artifacts in the Châtelperronian was spurious (e.g., Mellars 2010).

In a response to such claims, Caron et al. (2011) and Zilhão et al. (2011) countered that the new results could at best signify limited post-depositional displacement across the boundaries of adjacent levels. That such limited displacement existed was already known for levels VII and VIII, on the basis of the distribution of small fragments of ivory beads (d'Errico et al. 1998; Zilhão 2007), and for levels IX and X, on the basis of stone tool refits (Bodu 1990). This evidence in no way questions the site's overall stratigraphic integrity, and this for a number of reasons, namely:

(a) Mathematical simulation of the post-depositional movement of individual items across stratigraphic boundaries shows that the level of disturbance implied by Higham et al.'s and Mellars' interpretation of the new ORAU results is inconsistent with the vertical distributions of diagnostic stone tools, personal ornaments, bone artifacts and mineral pigments.
(b) In level X, where the Grotte du Renne's symbolic finds are concentrated, their distribution is fully congruent with that of the hearths and other habitation features.
(c) The stratigraphic outliers among the new dates reflect inaccurate results rather than displaced samples, the cause of the errors lying in the poor preservation of collagen, aggravated, in the case of bone tools, by contamination arising from their curation with glues and consolidants.
(d) The Bayesian model of dates and stratigraphy underpinning Higham et al.'s interpretation is flawed in their choice of priors and testable propositions; when testing the significance of outliers under phasing premises that are appropriate to the research issue at stake (which is whether the personal ornaments and Neandertal remains in level X could have been displaced from, respectively, levels VII and XI-XII), the new ORAU results fail to reject the association between Neandertals and symbolic artifacts in the Châtelperronian even in Higham et al.'s own terms, i.e., even under the assumption that their results are all accurate.

These arguments have since been vindicated by a larger set of dates, obtained by a different laboratory, on samples selected for their good collagen preservation and using the same pre-treatment, calibration and modeling tools as Higham et al. (Hublin et al. 2012a). The 26 radiocarbon results obtained for the Châtelperronian of the Grotte du Renne by Hublin et al.'s study place it in the ~41–45 ka cal BP interval, and the four obtained for underlying level XI place its last Mousterian occupation in the ~45–46 ka cal BP interval (Fig. 3.3). In turn, the five dates obtained for Protoaurignacian level VII all post-date ~41 ka cal BP, even though some corroborate that later Aurignacian components also exist therein, as otherwise indicated by a few Aurignacian I diagnostics found among the level's bone and stone tool assemblages (including a split-based bone point fragment; Julien et al. 2002).

In short: stratigraphic integrity is not an issue at the Grotte du Renne, and no reason exists to question the association of Neandertal fossils with personal ornaments in its Châtelperronian levels.

3.4 Early European Modern Humans: How Early?

Hopefully, Hublin et al.'s (2012a) results will have settled the Grotte du Renne controversy. From their dates, however, Hublin et al. also concluded that Neandertals "produced body ornaments in the northernmost part of [the Châtelperronian] geographical distribution only after modern humans arrived in western Europe and Protoaurignacian or Early Aurignacian populations occupied neighboring regions" and that "this new behavior could therefore have been the result of cultural diffusion from modern to Neandertal groups." On the logical side of things, this resurrection of the Acculturation model of the Châtelperronian championed by Hublin (e.g., Hublin 2000) is rather puzzling, as it ignores the evidence accumulated in the meanwhile for personal ornamentation in the Middle Paleolithic of Europe, ≥50,000 years ago (Zilhão et al. 2010a). On the empirical side of things, it is based on the premise that the Aurignacian and modern humans were present farther south and farther east at the time, ~45 ka cal BP, of Châtelperronian emergence. That such is the case has indeed been argued, but is the argument valid? This is the issue to which I now turn.

3.4.1 Grotta del Cavallo

The Uluzzian deposits excavated in the early 1960s at Grotta del Cavallo, in southern Italy, yielded two deciduous left upper molars: Cavallo-B, a dM^1 from spit EIII of level E, at the base of the Uluzzian sequence, and Cavallo-C, a dM^2 from immediately overlying spit EI-II. Churchill and Smith (2000), as others before them, had considered these teeth to be of Neandertal affinities, but Benazzi et al. (2011) assigned them to modern humans on the basis of a morphometric comparison employing a combination of two methods: the analysis of two-dimensional enamel thickness and of dental tissue proportions; and the analysis of the outlines of dental crown (for the Cavallo-B dM^1) and cervix (for the Cavallo-C dM^2). On both counts, the two teeth fell clearly outside the range of the comparative Neandertal sample and fully within that of the comparative modern human sample. However, before taking for granted that these results warrant Benazzi et al.'s conclusion that the people of the Uluzzian were modern humans, we need to discuss two issues that they failed to address: whether the comparative samples used are sufficient to assess the taxonomic issue at stake; and whether the two

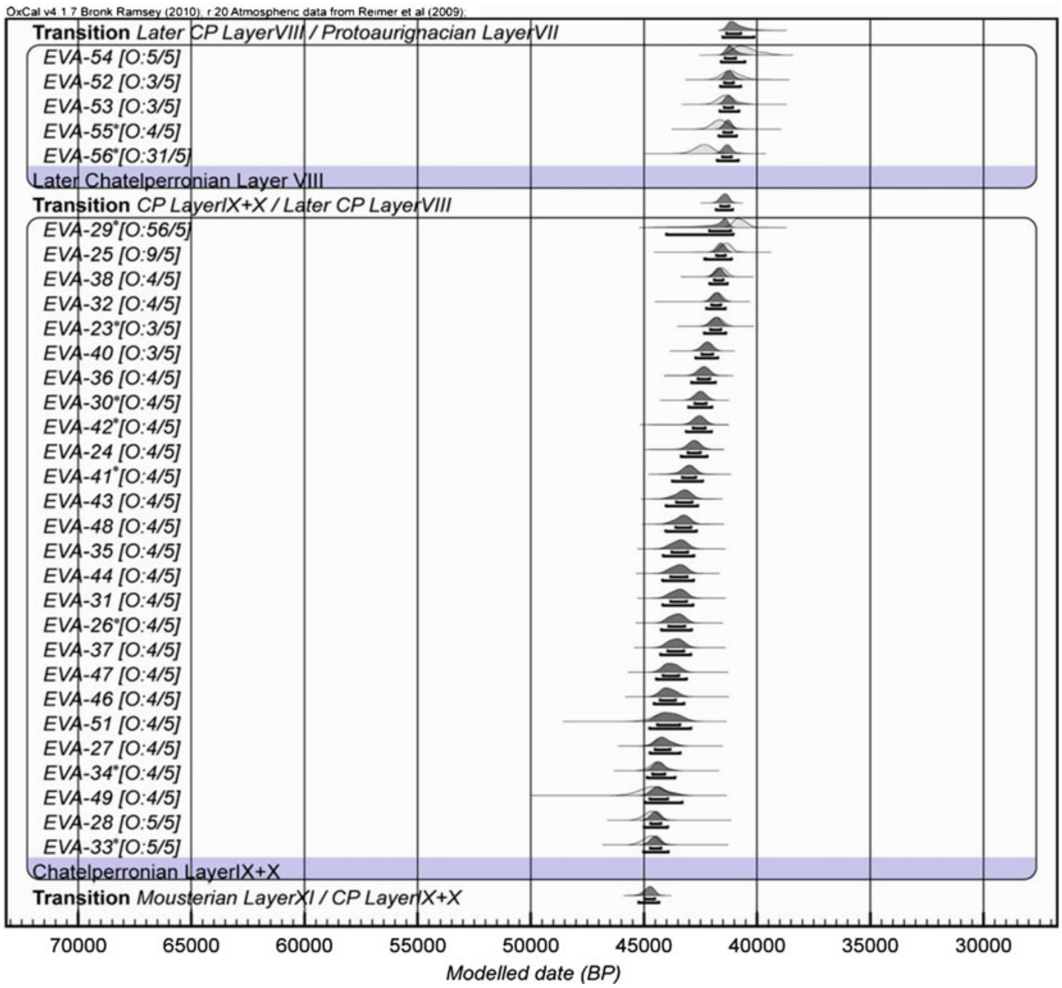


Fig. 3.3 Calibrated ages and boundaries, modeled with OxCal 4.1 (Bronk Ramsey 2009) and IntCal09 (Reimer et al. 2009), for the two blocks into which Hublin et al. (2012a) divided the Châtelperronian sequence of the Grotte du Renne (upper, level VIII; lower, levels IX–X); the samples marked with an asterisk bear anthropogenic modification. From Hublin et al. (2012a: Fig. 1), modified

teeth are in situ finds and truly represent the makers of the associated stone tools.

3.4.1.1 Tooth Morphology

Where the morphometric analysis is concerned, the main problem is representativeness: of the 11 Neanderthal teeth in the comparisons, one (from Subalyuk) is of unknown chronology, eight (from Krapina and Roc-de-Marsal) are of Marine Isotope Stage (MIS-) 5 age, and only two (those from Pech de l'Azé I) are not much earlier than the Cavallo fossils. In their graphs, Benazzi et al. (2011) do not individually identify the fossils, presumably because they assume that Neandertal anatomy remained static, there being no need, therefore, to consider the issues raised by the change through time toward more modern-like patterns seen among later Neandertals in post-crania (Trinkaus et al. 1999) as much as in skull and dentition (Wolpoff et al. 1981; Wolpoff 2002). Of particular relevance in this context is the fact that such directional change is most apparent in the contrasts between the Krapina (MIS-5) and Vindija (mid-MIS-3) fossil assemblages, i.e., in the evolution of Neandertals from south central Europe, the broader geographic region concerned by the Cavallo study. Therefore, all that can be concluded from Benazzi et al.'s study is that the Cavallo teeth are distinct from those of last interglacial Neandertals. Whether they are also distinct from those of the Neandertals from 50,000 years later remains an open issue, and all the more so since, as Churchill and Smith (2000) pointed out, the Cavallo teeth are taurodont, as is often the case with Neandertal deciduous molars but has never been observed among early modern human juveniles.

In addition, Benazzi et al. ignore the fact that a deciduous incisor, on which Gambassini et al. (2005) identified Neandertal apomorphies and a wear pattern similar to that seen in other Neandertal incisors, was also recovered in spit EIII of Cavallo (Riel-Salvatore 2009). On the face of the combined evidence, one would therefore have to conclude that Neandertals and moderns coexisted in southern Italy at the time of the Uluzzian and that the issue of who made it cannot be answered simply because both groups were implicated. Alternatively, and perhaps more sensibly, one might instead conclude: firstly, that our understanding of the variation in the dental morphology of Neandertals and modern humans from around the time of contact in western Eurasia is incomplete; and, secondly, that it is therefore unwarranted to assume that a clear-cut distinction existed at that time solely on the basis of the contrasts observed when comparing present-day humans with the Neandertals of 100,000 years ago.

The pertinence of this point is further highlighted by the misidentifications produced when Bailey et al. (2009) applied to the Romanian early moderns from Oase a set of diagnostic dental criteria designed to discriminate Neandertals from modern humans when dealing with isolated finds. Despite the large size of the comparative sample, it turned out that, if found loose, the Oase 1 mandibular teeth would have been classified as modern and the Oase 2 maxillary ones as Neandertal. Bailey et al. fell short of deriving the conclusion, but this outcome highlights the inappropriateness, with respect to the fossils of the contact period, of a framework where classical Neandertals are dichotomically contrasted with extant people or late Upper Paleolithic modern humans.

Bailey et al. used discrete crown traits, but using endostructural tissue properties instead does not necessarily clarify the picture, as shown by Bayle et al.'s (2010) study of the dentition of the Lagar Velho child, dated to ~30 ka cal BP. Five of the child's teeth were analyzed for their linear, surface and volumetric tissue proportions, of which the deciduous right upper central incisor came out as Neandertal-like, the permanent lower right first molar as modern human-like, and the other three (a deciduous lower right lateral incisor, a deciduous lower right canine and a deciduous lower right second molar) as intermediate on some parameters and modern human- or Neandertal-like in others.

In a subsequent paper dealing with the crown and cervical outlines of deciduous lower second molars, Benazzi et al. (2012) acknowledged this problem. Where the corresponding Lagar Velho tooth is concerned, they found it to be intermediate between Neandertals and modern humans in crown outline, and described this finding as corroborating the similar conclusion derived by Bayle et al. (2010) from tissue proportions. Benazzi et al. (2012) also found that the crown outlines of three other fossils, two Neandertals and one Upper Paleolithic modern, were misclassified by the predictive tool derived from the observed patterns. It is also noteworthy that the Neandertal sample in this study is composed of 14 specimens, of which 11 (those from Abri Suard, Krapina, Roc-de-Marsal and Scladina) are of MIS-5 age, two are of MIS-3 age (those from Couvin and Engis), and another, Cavallo-A, is, presumably, from a Mousterian level of unknown age underlying the site's Uluzzian deposit.

Subsequent to Benazzi et al.'s (2012) study, Le Cabec et al.'s (2013) analysis of anterior tooth root morphology and size also found a significant overlap between Neandertals and early modern humans. In light of these findings, of the problems encountered by Bailey et al. (2009) with the Oase fossils, and of the contradictions in expert opinion about the affinities of the teeth found in the Uluzzian levels of Cavallo, the conclusion is inescapable: for teeth from around the time of contact, secure classification in terms of the taxonomic categories of Human Paleontology may be possible for large sets (e.g., the Grotte du Renne's) but not for isolated finds. In short, the evidence upon which Benazzi et al. (2011) assign the Uluzzian to modern humans is inconclusive and insufficient to reject the hypothesis that the Cavallo teeth are Neandertal.

3.4.1.2 Dating

Benazzi et al.'s argument is further weakened by the fact that the new radiocarbon dates they obtained for the site suggest a more complex stratigraphic situation than they describe: "The Uluzzian deposits, about 80–85 cm thick, (…) are divided into Archaic Uluzzian (E III), Evolved Uluzzian (E II-I) and Final Uluzzian (D II-D Ib). They are separated from the upper part of the sequence by a stalagmitic crust (D Ia) and two sterile layers of volcanic ash (C II and C Ia-b). (…) Directly superimposed are Epigravettian horizons B II-B I (Romanellian and Epiromanellian *facies*), of much younger age (≈11,000 years BP)" (Supplementary Information, p. 2).

Contradicting this straightforward scenario of Late Epigravettian over Uluzzian with an intervening level of sterile volcanic ash of presumed Campanian Ignimbrite age (i.e., 39.3 ± 0.11 ka; de Vivo et al. 2001), four of the six dates for level D fall in the time range of the Early Epigravettian or the Protoaurignacian, which supposedly do not exist at the site (Fig. 3.4). The three dates in the Protoaurignacian age range are consistent with the presence in the stone tool assemblage of level D of a component with clear Aurignacian affinities, as pointed out by Gioia (1990). Based on this lithic evidence, I had previously suggested (Zilhão 2007) that the perforated *Columbella rustica* and *Cyclope neritea* shells from the "Evolved" and "Final" Uluzzian of Cavallo were likely to be intrusive items and, indeed, the Early Epigravettian date (~22.7 ka cal BP, confirmed by a repeat) was obtained on a specimen of the latter species. This Early Epigravettian date raises the question of whether the ash lenses capping level D really are Campanian Ignimbrite, but significant disturbance at this stratigraphic interface and affecting deeper levels in the sequence is additionally shown by the OxA-19257 result for level D; at ~45.3 ka cal BP, this date is some two millennia older than the single result obtained for underlying level E (OxA-19242, ~43.6 ka cal BP), and, given the relatively small standard deviations, the difference is statistically significant.

Early Epigravettian ages
Protoaurignacian ages
Uluzzian or Mousterian ages

OxA #	Date BP	Layer-Spit	Species
21072	19685±75	D I	*Cyclope neritea*
	19235±75		
19254	35080±230	D 1=DIb	*Nuculana* sp.?
19255	36260±250	D 2=DIb	*Dentalium* sp.
20631	36780±310	D II	*Dentalium* sp.
19257	42360±400	D 3=D II	*Bivalve* fragment
19258	36000±400	D 8=DII?	*Dentalium* sp.
19256	39060±310	E 1=E-D	*Dentalium* sp.
X-2280-16	38300±400	E 1=E-D	*Dentalium* sp.
19242	39990±340	E 4=EII-I	*Dentalium* sp.

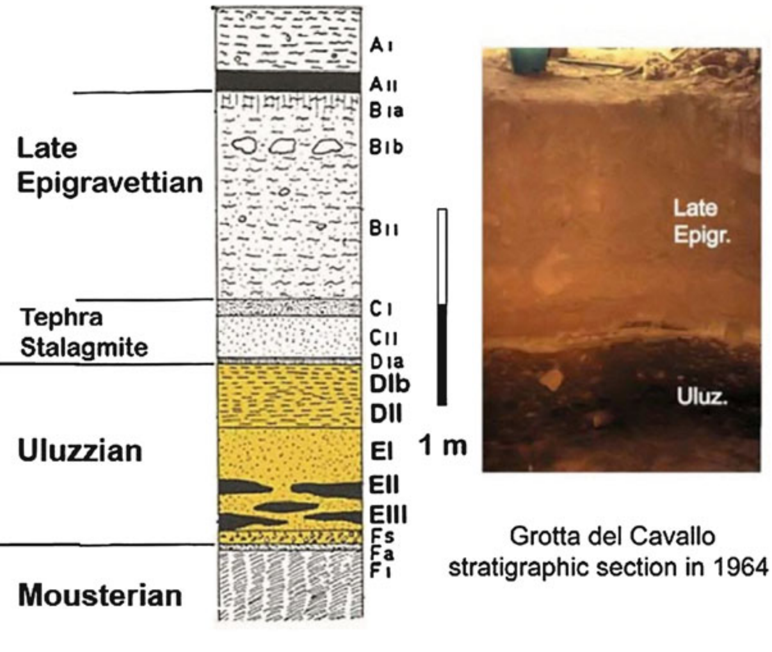


Fig. 3.4 Stratigraphy and dating at Grotta del Cavallo. *Left*: the uncalibrated radiocarbon results obtained on samples of marine shell ornaments from the Uluzzian levels. *Right*: detail of the succession at the interface between the Middle and the Upper Paleolithic (modified from Benazzi et al. 2011: Fig. S1, reproduced with permission from Macmillan Publishers Ltd/Nature)

In their analyses of, respectively, the stone and bone tool assemblages from the Cavallo Uluzzian, neither Riel-Salvatore (2009) nor d'Errico et al. (2012) spotted the presence of intrusive material in level E, and the ornament shell date of ~43.6 ka cal BP is consistent both with those published in d'Errico et al. (2012) for basal spit EIII of the site (on charcoal samples) and with age estimates for the Uluzzian elsewhere in Italy and Greece (Koumouzelis et al. 2001a, b; Higham et al. 2009). These observations warrant the overall stratigraphic integrity of level E, but do not exclude localized movement of individual, small-sized items across its boundary with the significantly disturbed level D, as suggested by the OxA-19257 result discussed above, in all likelihood an upwardly displaced sample.

3.4.1.3 An Open Issue

From the above, it is clear that even if the two teeth described by Benazzi et al. (2011), Cavallo-B and -C, are eventually shown to be of modern humans, their true association with the Uluzzian has yet to be securely established, and that can only come from the direct dating of the fossils themselves. This is because they come from spit EIII, which remains undated, and because the presence of intrusive items in overlying spits of the Uluzzian deposits is indicated by both dating results and stone tool typology. This precludes the use of the dates obtained for level D and for spit EI-II of level E as an absolute *terminus ante quem* for the material recovered in spit EIII.

The reasoning above assumes that the dates are chronologically related to the human activity recorded in the deposits from where they come. However, all of Benazzi et al.'s (2011) dates are on beach-collected marine shell beads; therefore, the interval between the death of the organism (the radiocarbon-dated event) and the time of collection (the archeological event of interest) is unknown and can be of several hundred or even thousands of years. In this regard, a relevant cautionary tale is provided by Douka's (2011) dating of a *Glycymeris* shell tool from Ksar' Akil (Lebanon) whose age turned out to be seven millennia older than that of the Evolved Aurignacian context where it was found. Conceivably, the dating anomalies pointed out in the preceding section could relate to this problem instead of reflecting episodes of human occupation that went unrecognized at the time of excavation. The dated *Cyclope* shell, for instance, could represent an object of Early Epigravettian age human-collected from an exposed beach in Late Epigravettian times, while the ~42.4 ka ^{14}C BP bivalve fragment from level D could represent an object of Mousterian age likewise human-collected in later, Uluzzian times. In order to avoid circularity and maintain logical consistency, introducing this possibility into the discussion implies that all of the results be treated as maximum ages. Doing so, however, also automatically means not using Benazzi et al.'s (2011) dates to support a minimum age, no matter which, for the fossils recovered in level EIII.

In these circumstances, hanging upon the Cavallo evidence the notion that modern humans made the Uluzzian is, at present, unwarranted. And even more so are, therefore, the speculations concerning the migration route followed by such putative pioneer moderns in order to travel from Africa to southern Italy (e.g., Moroni et al. 2012).

3.4.2 Kent's Cavern

The other European site where modern humans have recently been claimed to predate the ~41.5 ka cal BP time horizon is Kent's Cavern, in the southern United Kingdom. By their re-analysis of the three teeth in the KC4 maxillary fragment and the dating of associated faunal samples, Higham et al. (2011c) assigned the fossil to a modern human that would have lived in the region of 41.5–44.2 ka cal BP.

Bearing in mind the issues discussed above concerning the representativeness of comparative samples and the fuzziness of the contrasts between late Neandertal and early European moderns in many aspects of dental morphology, the first problem with this conclusion is that the taxonomic classification was proposed as a probabilistic statement, not a certainty. More importantly, even if the fossil is indeed one of a modern human, the age suggested for it by Higham et al. derives from a Bayesian model that makes three key assumptions: that the provenience information associated with the fossil is reliable; that the deposits in the Vestibule area of the site, from where KC4 was recovered in 1927, are characterized by a high degree of stratigraphic integrity; and that, in such a context, depth-below-datum is a good proxy for the time ordering of the dated samples. Zilhão et al. (2011) and White and Pettitt (2012), however, have since demonstrated these assumptions to be unwarranted. It is therefore sufficient here to briefly summarize the reasons why this is so:

(a) KC4 was recovered in the context of the excavations undertaken at the site by Arthur Ogilvie between 1926 and 1942. The coeval documentation published by White and Pettitt (2012) leaves no doubt that the bad reputation of this work, notorious for its lack of quality in both method and recording, is entirely deserved. From the photographic evidence (Fig. 3.5) we can see how the excavations were carried out: by untrained workmen using picks and shovels in quarry-like fashion and under poor lighting conditions, with finds being sorted by Ogilvie, with volunteer help, from sediment transported away in wheelbarrows.

(b) The maxillary fragment and the teeth, although anatomically associated, were recovered as scattered finds, the teeth dislodged from their sockets, spread over a distance of at least 60 cm and in an unrecorded part of Trench C, which, at around the time of discovery, was being excavated over an area of at least 15 m^2. The finds were reportedly made at a depth of 3.2 m below datum, but the precision of this information is illusory, as the datum used was the non-horizontal base of a granular stalagmite above the trench and the diaries acknowledge discrepancies of up to 30 cm between measurements made in different years.

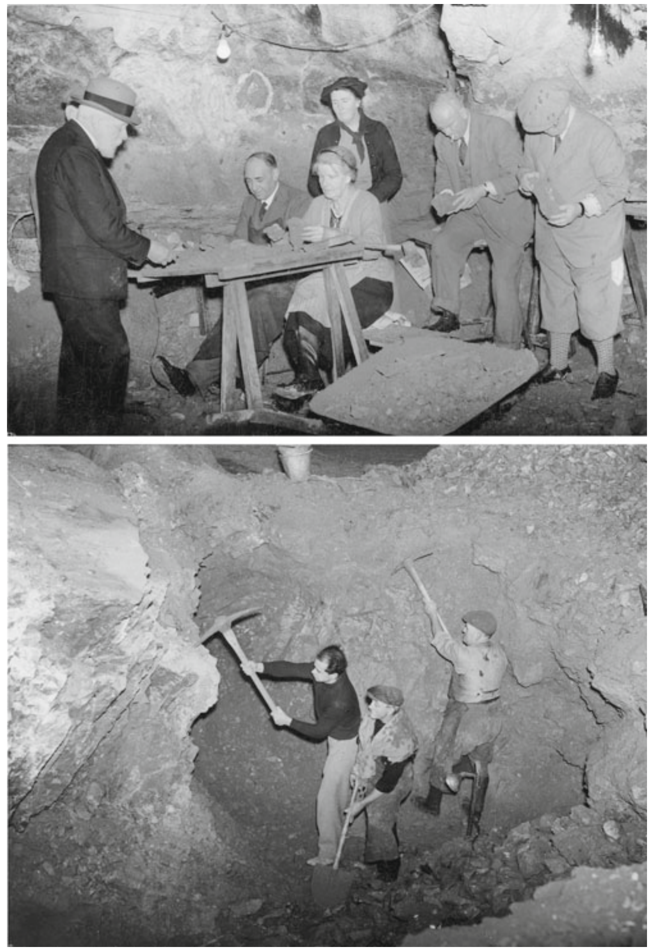


Fig. 3.5 Ogilvie's 1927 excavations at Kent's Cavern. *Below*: a view of the work in the Vestibule. *Above*: the spoil, transported by wheelbarrow, is sorted by Ogilvie and volunteers. From White and Pettitt (2012: Figs. 4–5), courtesy of the authors, reproduced with permission from Torbay Libraries

(c) The uncertainty in the position of the datum implies that the finds' depth information, even if deriving from actual on-the-spot measurements, cannot be used as a proxy for their relative age. Additionally, such a use would be legitimate only if the bedding were horizontal or nearly so, which is hardly the case.

(d) Above a stalagmitic floor encountered at a depth of ~2.4 m, the Trench C deposits were accumulated by torrential flooding, which implies that material of rather disparate ages could be included therein, and in no internal stratigraphic order. This jumbling effect would have been aggravated by post-depositional displacement (through solifluction, cryoturbation and animal burrowing). The pertinence of these points is highlighted by

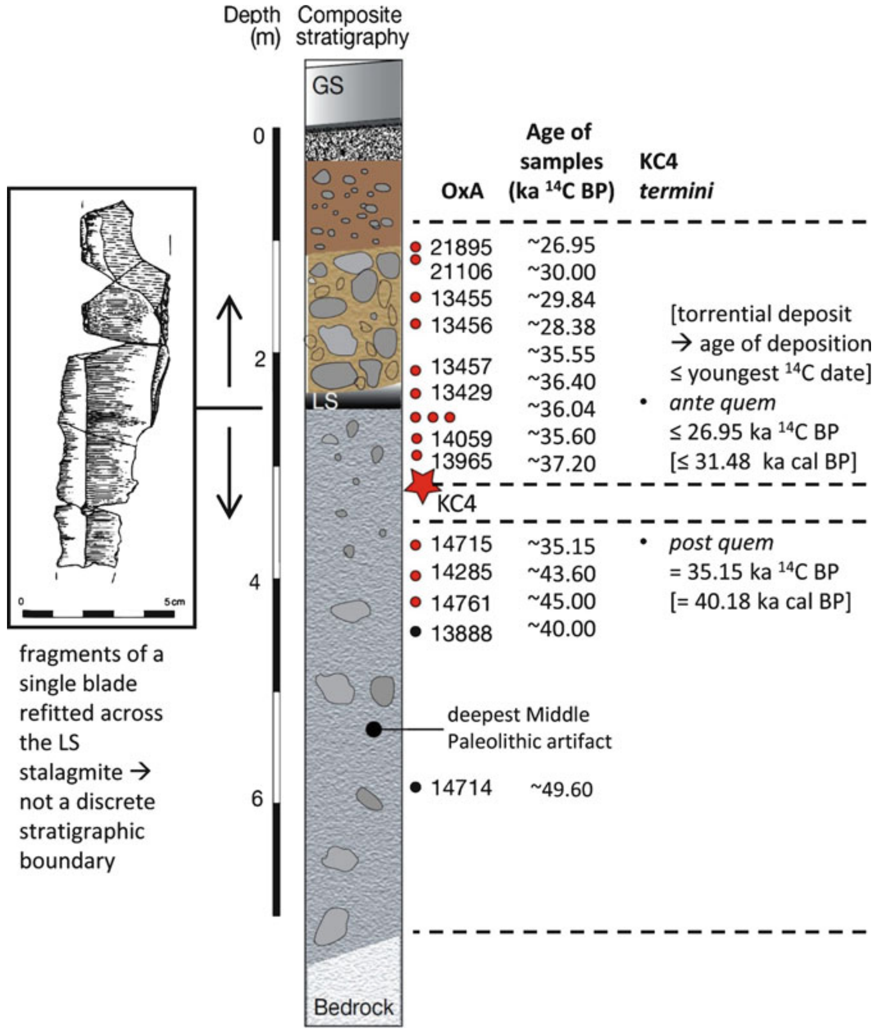


Fig. 3.6 *Right*: Schematic stratigraphy of Kent's Cavern Trench C (modified from Higham et al. 2011c: Fig. 2, reproduced with permission from Macmillan Publishers Ltd/Nature), and radiocarbon results obtained on faunal samples associated with the KC4 maxillary fragment; given the deposit's formation process, the only age constraint for the fossil is the *terminus post quem* provided by the ages obtained for samples reported to come from a lower elevation. *Left*: The different fragments of a single refitted blade from Trench C (reproduced from Jacobi and Higham 2011: Fig. 11.7, with permission from Elsevier Ltd) are reported to come from both above and below the LS stalagmite

refits that cut across stratigraphic boundaries, including major ones; namely, fragmentary flints recovered both below and above that 2.4 m stalagmitic floor have been shown to come from the breakage of a single blade (Fig. 3.6). This blade probably relates to the Evolved Aurignacian occupation of the site, evidence for which was found higher up in the sequence, and shows how material of such younger age could be present in, or have moved down the Trench C deposits to a depth comparable to that reported for the KC4 fossil.

(e) Even in the best scenario of horizontal stratigraphy and reliable elevation records, the genesis of the levels above the ~2.4 m stalagmitic floor implies that any finds made therein will be a combination of material coeval with the event that accumulated those levels and of older material plucked out from deposits eroded along the path of the torrential flow. Therefore, the date of formation of the levels above the ~2.4 m stalagmitic floor (and, consequently, the *terminus ante quem* they represent for the underlying strata) is given not by the oldest but by the youngest of the finds made therein—i.e., that *terminus* is ~27 ka ^{14}C BP (Fig. 3.6).

(f) The 2.4 m stalagmitic floor provides evidence that the Trench C sequence formed over at least two periods of accumulation, but the post-depositional disturbance observed across this boundary means that finds made at about its depth or somewhat lower down are not necessarily older. Therefore, the age of KC4 can at best be constrained by the results obtained for the samples collected well below it, at the base of the sequence. The *terminus post quem* so provided is one of 35.2 ka ^{14}C BP, the age of a rhino tibia sample (OxA-14715) reportedly found 45–75 cm deeper than the human fossil.

Under the assumption that these stratigraphic constraints are valid, it becomes apparent that the date obtained in 1989 for a sample from KC4 itself (30,900 ± 900 ^{14}C BP; OxA-1621) may well be not much off the mark, despite all the potential problems with its chemistry. Alternatively, we can treat the entire sequence as jumbled or potentially so, in which case little else can be said about the age of the fossil beyond that it must lie somewhere between the youngest and oldest of all the dates obtained for Trench C, i.e., in the 27–50 ka ^{14}C BP interval.

In short: contra the claims made by Higham et al. (2011c), KC4 provides no support for modern human presence in Europe prior to ~41.5 ka cal BP.

3.5 The Chronology of Modern Humans' Archeological Proxies

Neither the two Cavallo deciduous teeth nor the Kent's Cavern maxillary fragment support the presence of modern humans in pre-Aurignacian times, but the directly dated Oase fossils place them in at least Eastern Europe during the Protoaurignacian. As I have extensively discussed elsewhere (Zilhão 2007, 2011), relating the latter with modern humans therefore makes sense, and all the more so since a significant transformation of Europe's cultural geography occurred at the time: where, before, regionally diverse early Upper Paleolithic, so-called "transitional" industries existed, the pattern then became one of cultural homogeneity across vast regions of southern Europe and of mid-latitude central and western Europe.

In fact, the pattern extends to southwest Asia, given the technological and typological similarity between the Protoaurignacian and the Early Ahmarian (Belfer-Cohen and Goring-Morris 2003), and the latter's association with modern humans (the now lost child "Egbert" from Ksar' Akil; Bergman and Stringer 1989). As discussed above and in more detail elsewhere (Zilhão 2006b; Trinkaus and Zilhão 2013), the Protoaurignacian/modern human relation needs not be exclusive and Neandertal involvement in the spread of the technocomplex cannot be ruled out at present. Even so, these patterns imply that it does make sense to construe the Protoaurignacian as the spilling off of Near Eastern cultural developments into adjacent Europe as part of the process of modern human dispersal into the continent.

In the following, I will therefore discuss some recent work on the chronology of the Early Ahmarian and the Protoaurignacian, as well as related claims that both could have emerged well before ~41.5 ka cal BP. As some scholars have suggested that these technocomplexes are representative of Mediterranean areas only and that a separate spread of modern humans following the Danube corridor took place alongside or even at an earlier time (Conard and Bolus 2003; Mellars 2004; Higham et al. 2012), I will also discuss whether claims for the precocious occurrence of other forms of the Aurignacian in southern Germany and Austria are supported by dating and stratigraphy.

3.5.1 Early Ahmarian: Kebara

The cave of Kebara, Israel (Bar-Yosef and Meignen 2007), has been the key site for the radiocarbon dating of the Middle-to-Upper Paleolithic transition in Southwest Asia, but the results on charcoal reported by Bar-Yosef et al. (1996) (Table 3.1) for the corresponding levels show many inconsistencies. Two open air sites in the Negev (Boker Tachtit and Boker A; Marks 1983; Jones et al. 1983; Monigal 2003) also feature radiocarbon-dated occurrences of the Early Ahmarian, but the associated uncertainty intervals are too large.

Given this situation, I have suggested (Zilhão 2007) that the chronology of this technocomplex be anchored to the *terminus post quem* provided by the sequence of IUP (or Emiran) levels of the southern Turkish site of Üçağizli (Kuhn 2002, 2003; Kuhn et al. 2001, 2009), where the Early Ahmarian overlies the IUP (as is always the case in the region when both are present, namely at Ksar' Akil). This approach implies a time of emergence for the Early Ahmarian no earlier than ~40.0–41.5 ka cal BP, in the range of the European Protoaurignacian. Based on a new series of charcoal results (Table 3.2), Rebollo et al. (2011), however, have since claimed that, at Kebara, the Early Ahmarian emerged no earlier than ~49 and no later than ~46 ka cal BP.

This claim creates a contradiction with the chronostratigraphic framework based on the correlation of the three long sequences that span the Middle-to-Upper Paleolithic transition in the region: if Rebollo et al. (2011) are correct for Kebara, the Early Ahmarian would have begun there five to ten millennia earlier than at Ksar' Akil (only 150 km to the north) or Üçağizli (another 240 km further north), and would have been even earlier than the Mousterian of the former and the IUP of the latter. So, either the dates for the pre-Early Ahmarian deposits of Ksar' Akil and Üçağizli are greatly rejuvenated, something that Rebollo et al. (2011) do not suggest, or their interpretation of the Kebara results is flawed.

3.5.1.1 The Discrepancy Between ABA and ABOx

The charcoal samples collected in the field by Rebollo et al. (2011) come from Early Ahmarian units III and IV, and from Mousterian unit V. A first set of results was obtained on subsamples pre-treated at the Weizmann Institute with the standard ABA (Acid-Base-Acid) protocol and then measured at the ORAU; the second set was obtained on untreated subsamples processed with the ABOx-SC (Acid-Base-Oxidation-Stepped Combustion) protocol at the ORAU and measured there.

Contrary to what is usually the case (Brock and Higham 2009), the ABOx results came out systematically younger than those obtained with ABA, in some cases by more than five millennia. Rebollo et al.'s (2011) explanation for this anomaly is that the dating was carried out in the initial phase of setting-up ABOx at the ORAU and that, nowadays, the anomalous ABOx results would have been failed because of their low %C on combustion. They argue that, by rejecting results where this parameter is below 50 %, ABOx and ABA

Table 3.1 The radiocarbon dates on charcoal samples reported by Bar-Yosef et al. (1996) for Kebara

Provenience	Lab #	Date BP
Unit VII square Q19	OxA-3981	>44,800
Unit VI square P24	Gif-TAN-90029	>48,000
Unit Vw square Q15d	Gif-TAN-90030	>46,900
Unit Vw square Q16, near burrow	OxA-1568	38,000 ± 2,100
Unit V square Q15d	OxA-3980	>44,800
Unit V square Q14d	OxA-3979	>44,000
Limit Unit IV–V, in Q16b/Q15d	Pta-5141	43,700 ± 1,800
IVB	Pta-5002	42,500 ± 1,800
IVB	Pta-4987	42,100 ± 2,100
IVB, adjacent to burrow	OxA-3978	28,890 ± 400
IIIB	OxA-3976	43,500 ± 2,200
IIIBf	OxA-3977	>43,800
IIIBf	Gif-TAN-90037	>42,500
IIIBf	OxA-1567	35,600 ± 1,600
IIIBf	Gif-TAN-90168	>41,700
IIIB	Pta-4267	36,100 ± 1,100
IIf hearth	Gif-TAN-90028	34,300 ± 1,100
IIf hearth	Gx-17276	42,800 ± 4,800
IIf	OxA-1230	36,000 ± 1,600
IIf above hearth	Gif-TAN-90151	32,670 ± 800
II, in burrow	Pta-4263	31,400 ± 480
II, in burrow	Pta-4269	28,700 ± 450
II top	OxA-3975	33,920 ± 690
I base	OxA-3974	34,510 ± 740
I	Pta-4268	32,200 ± 630
I subsurface	Pta-4247	22,900 ± 250

do agree; for the Kebara samples, the latter would be generally more reliable because the rejuvenation would be caused by carbon dioxide adsorbed from the atmosphere by "siliceous aggregates that are not eliminated during the ABA and ABOx pre-treatments and are present in relative higher concentration in the ABOx fractions" (p. 2429).

However, for a radiocarbon measurement in this age range to be rejuvenated to the extent seen in, for instance, the pair of subsamples from unit V sample R19V2 (OxA-V-2253-46, 45,200 ± 700 ^{14}C BP, by ABA; OxA-X-2252-7, 36,300 ± 650 ^{14}C BP, by ABOx), the proportion of modern (e.g., 20 year-old), atmospheric-induced contamination remaining in the ABOx-ed subsample would have to be 0.73 % (Fig. 3.7). This is under the assumption that the ABA result is accurate, but Rebollo et al.'s (2011) explanation implies that their ABA results are also affected by modern contamination, even if less so. As ABA dates in the range of 51.5 ka ^{14}C BP were obtained for unit V, we can place at ~0.15 % the maximum level of modern contamination admissible for such dates because, even if a sample's true age is infinite, 52,250 is the oldest radiocarbon age measurement possible at that level (Fig. 3.8); or, put another way, because higher levels of modern contamination will result in dates younger than 52,250 even for samples of infinite age.

Given these constraints, let us postulate a general level of 0.10 % modern contamination for the ABA subsamples and recalculate the contamination of the ABOx subsamples implied by the discrepancy seen in the pair of results obtained for unit V sample R19V2. The true age of this sample would then be 47,800 instead of the measured 45,200, i.e., the ABOx result of 36,300 would be rejuvenated by 11,500 years instead of 8,900, and the level of modern contamination implied would therefore be of 0.83 % instead of 0.73 %. At these levels, the oldest radiocarbon age measurements possible are 38,510 and 39,541, respectively (Fig. 3.8), so postulating such general levels of contamination for the ABOx results is inconsistent with the ABOx date of 50,600 ± 1600 ^{14}C BP (OxA-18803) obtained for unit V sample R19aV_4 (Table 3.2) even if the ABA dates are deemed exempt of any form of contamination.

If, instead, we take this 50,600 result as an indicator of the maximum extent to which the ABOx dates could have been affected by modern contamination, then the corresponding level is 0.18 % (Fig. 3.8). Averaging Rebollo et al.'s (2011) validated ABA results for units III and IV would place them at ~42,000 and ~42,625, respectively. Therefore, if these ABA results are accurate and the ABOx-ed subsamples retained 0.18 % of modern contaminating carbon, then the

Table 3.2 The AMS radiocarbon dates on charcoal samples from Kebara published by Rebollo et al. (2011). The age measurements were carried out at the ORAU. The ABA results are on subsamples pre-treated at the Weizmann Institute, the ABOx results are from a different set of untreated subsamples separately processed at the ORAU

Sample number	Sample name	Square	Unit	Pre-treatment	Weight loss % after pre-treatment	%C (combustion)	OxA	Date BP
1	R16cIIIb_2	R16c	IIIb	ABA	74.9	58.0	V-2253-42	40,500 ± 400
						60.9	V-2253-43[a]	40,600 ± 400
				ABOx-SC	95.4	72.1	18,458	41,050 ± 450
2	R17aIIIb,f	R17a	IIIbf	ABA	53.9	57.0	V-2220-42	42,600 ± 500
				ABOx-SC	98.4	64.3	18,791	42,800 ± 650
3	R16cIIIb_1	R16c	IIIb	ABA	56.4	59.7	V-2220-41	42,850 ± 550
				ABOx-SC	94.3	49.3	X-2222-32	41,400 ± 1,200
4	R19aIV_1	R19a	UP Channel	ABA	68.0	55.7	V-2220-43	34,540 ± 250
5	R17aIV	R17a	IV	ABA	48.0	69.8	V-2253-44	41,650 ± 450
				ABOx-SC	84.7	67.7	18,459	40,400 ± 400
6	R19aIV_2	R19a	IV	ABA	79.6	55.9	V-2253-45	43,600 ± 600
				ABOx-SC	95.7	29.5	18,402	40,300 ± 550
				ABOx-SC	96.5	27.7	18,801[b]	35,160 ± 310
7	R19aIV_4	R19a	IV	ABA	77.0	46.7	V-2269-35	36,110 ± 330
				ABOx-SC	97.4	10.6	X-2264-29	40,500 ± 1,200
8	R19aV_2	R19a	V	ABA	77.9	53.8	V-2253-46	45,200 ± 700
				ABOx-SC	94.9	13.3	X-2252-7	36,300 ± 650
9	R15cV	R15c	V	ABA	70.3	62.3	V-2267-43	46,250 ± 650
				ABOx-SC	89.3	51.7	18,792	44,800 ± 650
10	R19aV_4	R19a	V	ABA	77.0	55.6	V-2267-45	49,600 ± 1,000
				ABOx-SC	93.8	33.1	18,803	50,600 ± 1,600
11	R19cV	R19c	V	ABA	88.6	56.6	V-2267-46	51,500 ± 1,200
				ABOx-SC	91.0	21.8	18,804	44,300 ± 1,000

[a]AMS measurement repeated for this sample as a standard procedure at ORAU

[b]Sample pre-treated twice, and each fraction subjected to AMS measurement, as a standard quality control procedure at ORAU

ABOx measurements for these units should have been ~40,000 (Fig. 3.8; specifically, ~39,690 for unit III and ~40,150 for unit IV). This is in the range of what was actually measured, except for OxA-18801, an ABOx result of 35,160 ± 310 ^{14}C BP obtained for unit IV. For this particular result, 0.77 % is the level of modern contamination implied if the real age of the sample was ~42,000 (Fig. 3.8)—about the same as that implied under comparable assumptions for the statistically identical ABOx result of 36,300 ± 650 ^{14}C BP (OxA-X-2252-7) for unit V (Fig. 3.7). Conversely, postulating a 0.18 % level for OxA-18801 produces an age shift from 35,160 to only 36,380, which keeps it fully within the Early Ahmarian age range implied by regional chronostratigraphy and clearly outside the range of the other ABOx results—exactly as discussed above for OxA-X-2252-7.

From this exercise we can draw two conclusions. The first is that the discrepancy between the ABA and ABOx results cannot be explained by a lab-specific or protocol-specific contaminating factor acting upon the samples in a regular, consistent manner; clearly, the contamination problems are sample- or subsample-specific and, consequently, calculating a parameter that would enable us to estimate the extent to which each individual result deviates from the sample's real age is not possible. In these circumstances, the validity and archeological significance of the results can only be assessed against external criteria, namely those of stratigraphic consistency, not against the intrinsic chemical properties of the samples themselves, even when these meet pre-specified quality controls. The alternative approach is to sort out the "good" from the "bad" dates on the basis of inferred levels of modern contamination that would explain the anomalies. Such post-hoc assigning of the level of contamination that would bring the "bad young" result obtained for a given sample in line with the "good old" result expected would constitute, however, an evidently circular, and therefore invalid, argument.

The second conclusion is that many if not all of Rebollo et al.'s (2011) results are likely to correspond to minimum ages only. In fact, under their "atmospheric adsorption by siliceous aggregates" explanation and consequent admission that the ABA dates are also affected by the problem, a residual modern contamination level of 0.10 % suffices to shift the 51,500 result for unit V to 59,000 (Fig. 3.7)—i.e., to beyond the ten half-lives accepted by the radiocarbon dating

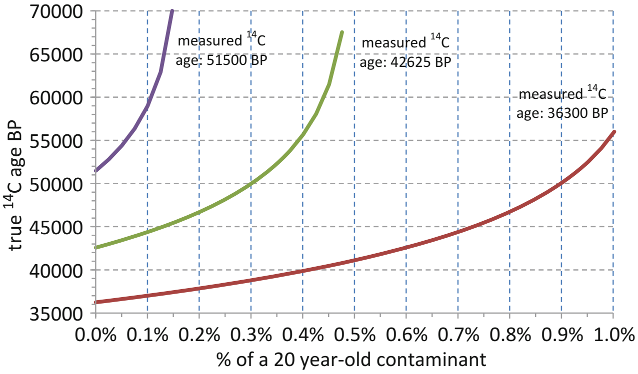


Fig. 3.7 The true age that samples radiocarbon-dated to 51,500, 42,625 and 36,300 BP would have if a low-level, atmospheric-induced (here modeled as 20-year old) contamination remained after pre-treatment. For such dates to be returned with modern contamination levels above, respectively, 0.15 %, 0.48 % and 1.10 %, the samples would have to be of infinite radiocarbon age

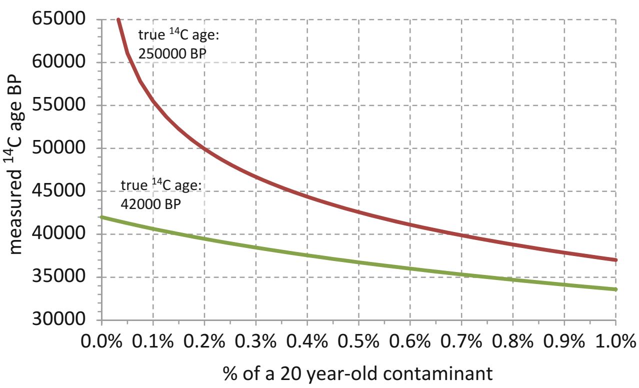


Fig. 3.8 The age measurements that would be obtained for a sample with a true radiocarbon age of 42,000 BP and for a sample of infinite age (here modeled as 250,000 BP) if a low-level, atmospheric-induced contamination (here modeled as 20-year old) remained after pre-treatment. The infinite age curve can also be read as returning the maximum age measurement possible for the given level of a sample's contamination by modern carbon

community as the practical limits of the method. This threshold is also crossed for the other ABA results of Rebollo et al. (2011) given a somewhat higher value of 0.40 %; but even the 0.10 % level suffices to bring their ABA dates for units III, IV and V to an age range (≥45,000 ^{14}C BP, i.e., ≥48,000 cal BP) that fully overlaps that determined by TL for underlying units VI and VII—48.3 ± 3.5 ka and 51.9 ± 3.5 ka years ago, respectively (Valladas et al. 1987).

Given the contamination issues, it is thus entirely plausible that all of Rebollo et al.'s (2011) samples, including those collected in the Early Ahmarian levels, are in fact of Middle Paleolithic age. Indeed, the possibility that these levels contain inherited or intrusive charcoal was already implicit in the set of ABA dates published by Bar-Yosef et al. for unit III. Besides three infinite results, this set included three finite ones—43,500 ± 2,200 BP (OxA-3976), 36,100 ± 1,100 BP (Pta-4267), and 35,600 ± 1,600 BP (OxA-1567) (Table 3.1). Rebollo et al. (2011, Fig. 4A) accept their accuracy and combine them in a single phase to produce a Bayesian model putatively supporting the notion derived from their own results that the start date for this Early Ahmarian unit falls in the 46–49 ka cal BP range. However, despite the large standard deviations involved, the oldest of Bar-Yosef et al.'s finite results for unit III, which does fall in the same time range as those obtained by Rebollo et al. (2011), is clearly statistically distinct from the others; and, if two different populations of age measurements exist in a given stratigraphic unit, then, by definition, this unit cannot be modelled as a single occupation phase.

Modelling modern contamination as above and under assumptions that do not shift to radiocarbon infinity the older of Bar-Yosef et al.'s finite results for unit III, we see that, because of exponential decay, the corresponding impact is insufficient to change the younger ones. The averaged result of these younger results is 35.8 ka ^{14}C BP and, for modern contamination values up to 0.65 %, the corresponding contamination curve runs broadly parallel to the 36,300 curve in Fig. 3.7; using this graph, it is therefore easy to obtain the true ages—37,100 and 36,500, respectively—into which a 35,800 result would translate with contamination levels of 0.18 and 0.10 %. However, considering the associated uncertainty intervals, 35,800, 37,100 and 36,500 are in this case statistically the same radiocarbon age. Therefore, modelling such low levels of modern contamination is insufficient to impact the chronological significance of the Pta-4267 and OxA-1567 measurements, which is that they place the Early Ahmarian of Kebara in full contemporaneity with the Protoaurignacian of Europe; as can also be easily verified in Fig. 3.7, the level we have to model in order to bring these two results to the range of Rebollo et al.'s (2011), i.e., to ~42 ka^{14}C BP, is 0.63 %. As a last resort, one could hypothesize that such a level pertained in the specific case of the samples from unit III; the hypothesis, however, would be inconsistent with the fact that seven out of the nine ABA dates obtained for it by both Bar-Yosef et al. and Rebollo et al. (2011; Tables 3.1 and 3.2) are older than the limit—40.7 ka ^{14}C BP—beyond which finite age measurements become impossible with that level of contamination (Fig. 3.8).

To sum up, the impact of atmospheric-induced, modern contamination cannot provide an overarching explanation for the discrepancy between Rebollo et al.'s (2011) ABA and ABOx results. Depending on model assumptions, the levels of such contamination implied by the discrepancy would either bring all of their Early Ahmarian results into the range of those obtained by TL for the underlying Middle Paleolithic, or be insufficient to age in any significant manner those obtained by ABOx that fall in the 35–36 ka ^{14}C BP range. Either way, another conclusion is inescapable: even though the artefacts in Kebara units III and IV are of Early Ahmarian affinities, a significant proportion of the charcoal therein is of an earlier, Middle Paleolithic age. This may seem counter-intuitive at first glance, but is in fact supported by the site's geological study, to the implications of which I now turn.

3.5.1.2 Implications of Site Formation Process for the Age of the Dated Carbon

Under the premise that the valid ABA results for unit III are Bar-Yosef et al.'s Pta-4267 and OxA-1567 (35.6–36.1 ka ^{14}C BP, ~40.0–41.5 ka cal BP), two explanations are conceivable for the older results: they are accurate but reflect the true age of charcoal that, although recovered in units III and IV, is reworked from the Mousterian; or they are inaccurate and reflect some form of ancient (instead of modern) contamination, one resulting from the physical presence in the Early Ahmarian samples of charcoal (or burnt organic particles) of an earlier, Mousterian age, or from the chemical interaction between such components and the Early Ahmarian charcoal.

The site formation process described by the excavators for the accumulation of Kebara's Upper Paleolithic deposits supports the presence of Mousterian charcoal in units III and IV of the profile sampled by Rebollo et al. (2011): "… the onset of the collapse and subsequent filling of the cave (…) into the Upper Paleolithic took place during relatively wetter conditions" as demonstrated "not only by the constant finely laminated nature of these deposits, which were placed by low energy sheetflow, but also by the presence of diatoms, which indicate a wet substrate in the cave in the Upper Paleolithic layers" (Goldberg et al. 2007, p. 86). These layers were laid down over a slope formed as a result of erosion and subsidence processes that, in this part of the cave, deformed the surface of the Middle Paleolithic deposit prior to (and continuing throughout) the accumulation of the Upper Paleolithic layers. For water-saturated material, such a configuration implies instability; until an equilibrium is reached, the sediments will flow like a fluid, entailing the redeposition along the slope of material derived from higher up, i.e., in this case, from Middle Paleolithic units located toward the entrance of the cave (Figs. 3.9 and 3.10). As these Middle Paleolithic units are made up of ashy and organic-rich burned material, the formation process of the Early Ahmarian units from the area of the cave that was sampled for radiocarbon dating implies that abundant amounts of inherited charcoal and carbon-rich soil particles of Middle Paleolithic age must exist therein.

The implications of this inference are obvious, but it must be borne in mind that in and of itself the inference I am making here is nothing new; it is a restatement of Goldberg et al.'s (2007) unambiguous description of the Upper Paleolithic deposits of Kebara: "Inside the cave they grade laterally to thinly bedded silt- and sand-sized aggregates composed of reworked Middle Paleolithic hearths, ashes, and other Mousterian sediments that were eroded after the major phase of subsidence" (p. 50); "the composition of these deposits indicates that they are largely a mixture of reworked burned materials and some terra rossa, much of which was derived from upslope to the west" (p. 73).

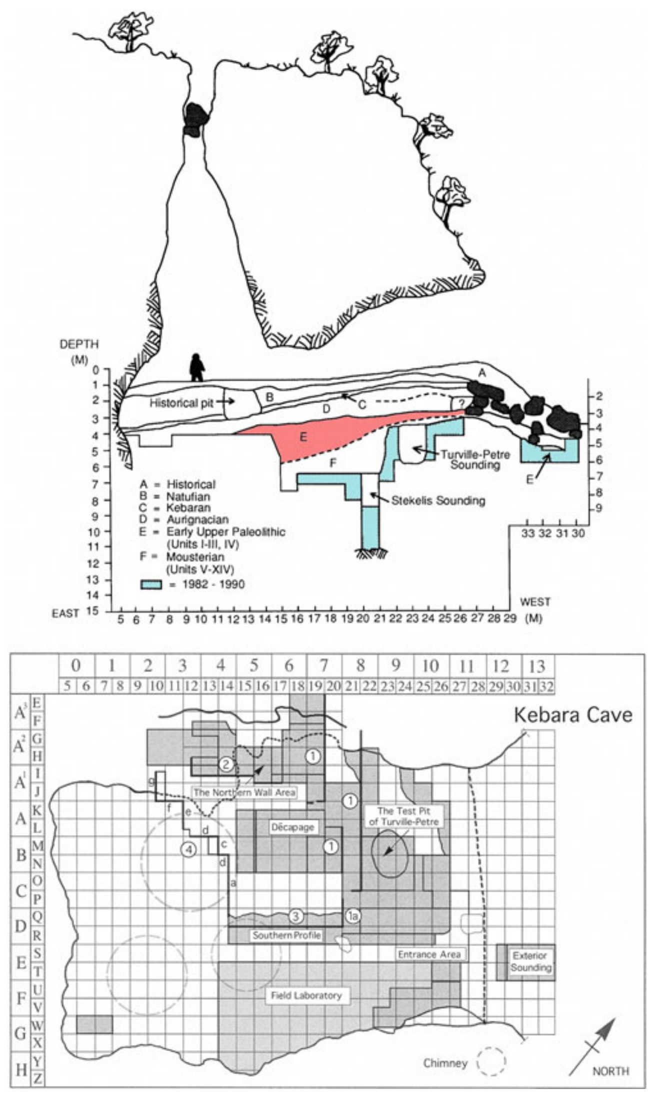


Fig. 3.9 Kebara. *Bottom*: Site plan with indication of the grid (the 2 × 2 m units are from Stekelis' 1951–1965 excavations, the 1 × 1 m units are from the 1980s work; courtesy Kebara Archive, modified) and of the excavated areas and their designation (*1* western sector; *1a* west profile composite; *2* northern sector and kitchen area; *3* south sector and composite profile; *4* eastern sector and composite profile). *Top*: Schematic cross-section of the site, with indication of the main stratigraphic blocks (courtesy Kebara Archive, modified); when viewed in two dimensions, the Early Ahmarian deposit has a wedge shape reflecting a formation process primarily involving the accumulation against the back wall of reworked Middle Paleolithic sediments derived from the entrance; however, interspersed within the deposit, there are several in situ partial hearths (black charcoal and white ashy layers; cf. Fig. 3.10), often cut by erosion processes (mostly sheet flow spreading the ashy components)

Some of Rebollo et al.'s (2011) samples are reported to come from the in situ hearth features found interspersed

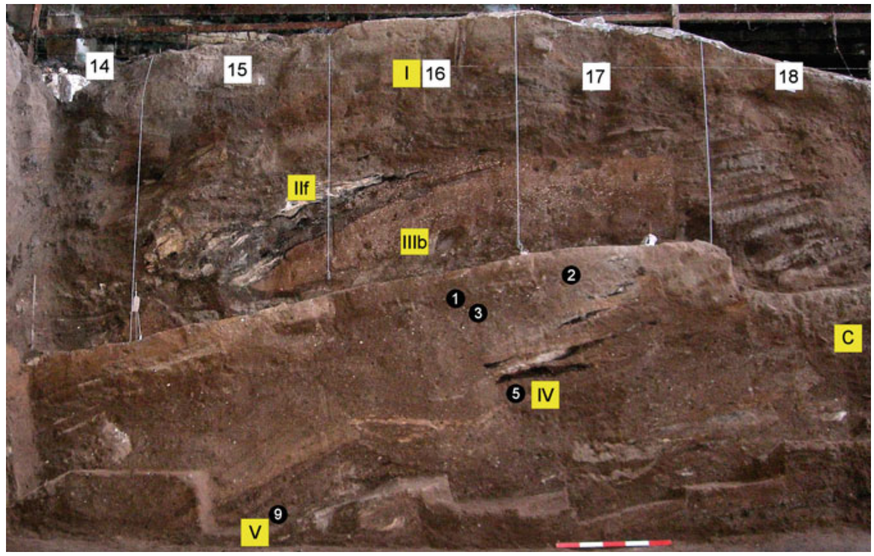


Fig. 3.10 Kebara. Columns 14–18 of the south profile along mid-row R of the 1990s grid, after the 2006 sample collection season (courtesy Kebara Archive, modified), with indication of the position of samples 1–3, 5 and 9 of Rebollo et al. (2011) and of the major stratigraphic units (the letter "C" indicates a channel cut into units III-V and filled with Upper Paleolithic materials); note that, according to Goldberg et al. (2007), the sedimentary matrix of units III and IV includes reworked burnt and phosphatized material, derived from Middle Paleolithic levels located at higher elevation elsewhere in the cave

within units III and IV. This is not the case, however, with all of them: "Collection of charcoal samples for this study was conducted during the 2006 excavation season, and was *primarily* limited to hearth areas which we considered to be well-defined intact contexts" (p. 2426, my emphasis). Also, of the 23 samples obtained, only 11 were eventually found to be suitable for dating, and only three of them (two from unit III and one from unit IV) are piece-plotted. Since the specific information is missing from Rebollo et al.'s (2011) provenience table, it is unclear whether the samples from units III and IV that ended up being dated are among those collected in the hearths. The projection over the south profile of the two that were both dated and piece-plotted (samples 1 and 3; cf. Fig. 3.10, where the information is taken from Rebollo et al. 2011, Fig. 2) suggests not. And, of those that were not piece-plotted, only sample 2 can be assumed to be among those collected in a hearth feature, given its "IIIbf" labeling (where "f" stands for the French word *foyer*, or hearth).

The important point, however, is that, in the case of Kebara units III and IV, the likelihood that a sample is of Mousterian age (or contaminated by carbon of that age) is not necessarily smaller simply because it was collected in a hearth context. The hearths in those units are not constructed, namely, they do not correspond to basins with a fill entirely made up of material combusted after the excavation of the basin itself. Instead, they correspond to areas where the fuel was burnt directly on the ground surface and, therefore, ones where the sediments bearing the distinctive characteristics of in situ fire activity include material present in the pre-existing, surface-exposed deposits. Additionally, it must be borne in mind that not all of the dated samples were individual charcoal pieces: "when several pieces had to be pooled in order to obtain the minimal necessary weight (around 100 mg) it was known from field observations that the charcoal fragments were all derived from one depositional unit" (Rebollo et al. 2011, p. 2426).

Given the presence of reworked charcoal in the sediments upon which the in situ hearths were fired and the composite nature of at least some of the dated samples, it is clear that their physical contamination with charcoal or charred organic material of Middle Paleolithic age is more than a distinct possibility. The discrepancies in the results obtained by Rebollo et al. (2011) for subsamples of the same sample when using ABOx instead of ABA (and, in the case of R19aIV_2, even for two separately processed ABOx dates; Table 3.2) suggest, however, that the problems go beyond the physical displacement of charcoal fragments, especially in the light of the micromorphological observations reported by Goldberg et al. (2007, p. 86): "Ensembles A and B [in the south profile, units Ia to V-upper, including Early Ahmarian units III and IV] in the interior commonly contain crudely bedded aggregates and masses of reddish silty clay. In addition, however, they commonly contain charcoal and, more importantly, finely comminuted pieces of charred organic matter that are incorporated into the matrix." Because of their small size, these particles cannot be removed by mechanical methods prior to chemical pre-treatment. At Kebara, what is returned as a date is therefore the percent ^{14}C content of the carbon extracted from samples that contain inherited organic matter particles; consequently, whether such carbon is entirely endogenous to the wood burnt in the firing event whose age one intends to measure is clearly an open issue. This is implicit in Rebollo et al.'s (2011) rejection of 12 of the 23 samples originally collected on the grounds that the weight loss undergone at the end of the ABA pre-treatment—a quality indicator for charcoal samples—was too high. However, weight loss was still quite significant even for those 11 samples that were considered

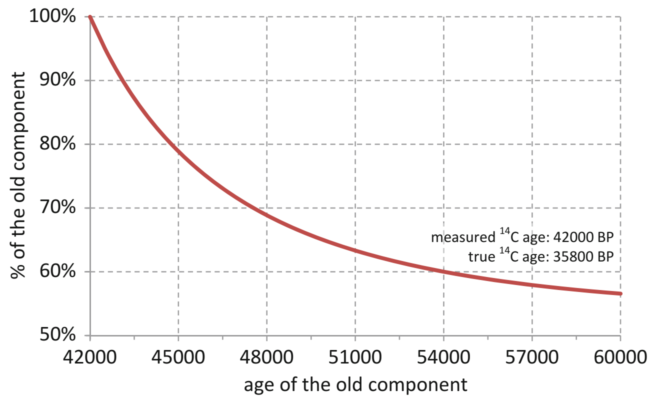


Fig. 3.11 The impact of ancient contamination in the dating of the Kebara charcoal samples. A sample with a radiocarbon age of 35,800 years will return a 42,000 result if 62.7 % of the carbon in it derives from a source with a radiocarbon age of 51,500. Higher percentages will be required for <50,000 year-old contaminants, while a 42,000 result for a 35,800 sample requires at least 53.8 % of exogenous carbon even if the contaminants are of infinite radiocarbon age

reliable—between 48.0 and 79.6 % (65.0 ± 12.5 %) for the six samples from units III and IV (Table 3.2).

In this respect, note that, as illustrated in Fig. 3.11, a sample with a true radiocarbon age of 35,800 years (the average of Pta-4267 and OxA-1567) can indeed yield an age measurement of 42,000 (the average of Rebollo et al.'s (2011) three ABA measurements for unit III) if 62.7 % of the carbon in it has a radiocarbon age of 51,500 years (Rebollo et al.'s (2011) ABA date for Middle Paleolithic unit V). Because of exponential decay and the half-life of radiocarbon, increasing the age of the contaminant does not much change the amount required for the shift, which has to be at least 53.8 % even if the contaminant is of infinite radiocarbon age. In theory, these values could explain Rebollo et al.'s (2011) results if we reversed their argument concerning the reliability of ABOx versus ABA.

For instance, in the case of samples R19aIV_2 (unit IV) and R19aV_2 (unit V), ABOx-dated to ~35–36 ka ^{14}C BP (Table 3.2), let us assume that only ABOx was capable of removing all contaminants, including old ones; the ABA results for those samples (~43–45 ka ^{14}C BP; Table 3.2) would then be explained by 77.2–81.8 % of 50,000 year-old carbon remaining in the corresponding subsamples after pretreatment. This reasoning implies that unit V sample R19aV_2 is of Upper Paleolithic age, but that Upper Paleolithic charcoal could be present in unit V is implicit in Rebollo et al.'s (2011, p. 2431) acknowledgment that it "contains mostly a Late Mousterian assemblage with less than 10 % of small tool types (including a few bladelets) traditionally attributed to UP. This intrusion is possibly due to trampling and vertical penetration through minicracks observed in the fine clay *terra* rossa, sediments that originated from the entrance of the cave." Where the Middle Paleolithic deposits of the south profile, from where Rebollo et al.'s (2011) samples come, are specifically concerned, such intrusions are explicitly mentioned by Goldberg et al. (2007, p. 55): "some layers in uppermost part contain Upper Paleolithic material."

The proportions of older carbon required by this "chemical" contamination scenario are, however, unrealistic. They are also so high that, for all practical purposes, such a scenario cannot be distinguished from that of "physical" contamination—of the deposits or, in the case of the composite samples, of the samples themselves. In any case, whichever the cause, the problems with the Kebara samples clearly preclude the use of Bayesian modeling, which requires certainty about the accuracy of both the results and their time ordering. That cannot be the case at Kebara, where (a) introducing the possibility that the ABA results are modern-contaminated, even if only quite moderately, implies that the entire set could be made up of infinite ages, and (b) introducing the possibility that only ABOx managed to remove all contaminants, both modern and ancient (and, even so, not always), implies that only two of Rebollo et al.'s (2011) results are consistent with site stratigraphy and regional chronostratigraphy (and, for one, only if the sample is interpreted as displaced).

3.5.1.3 An Alternative Interpretation of the Kebara Dates

The only other conceivable approach is to follow the argument that the ABOx results are somehow unreliable, perhaps for reasons related to the experimental phase during which they were produced, and remove contamination from the discussion by accepting that ABA worked well with the Kebara samples—as suggested by the fact that all of Rebollo et al.'s (2011) such samples have %C on combustion values between 46.7 and 69.8 (Table 3.2). In doing so, however, we also need to consider the ABA results of Bar-Yosef et al., and there is then no escaping the conclusion that two populations of radiocarbon dates exist in the Upper Paleolithic levels of Kebara (Fig. 3.12): one at ~35.8 ka ^{14}C BP (~41.0 ka cal BP), and another at ~ 42.0 ka ^{14}C BP (~45.4 cal BP). Which of these two sets relates to the Early Ahmarian is something that, against the site's dating background, can

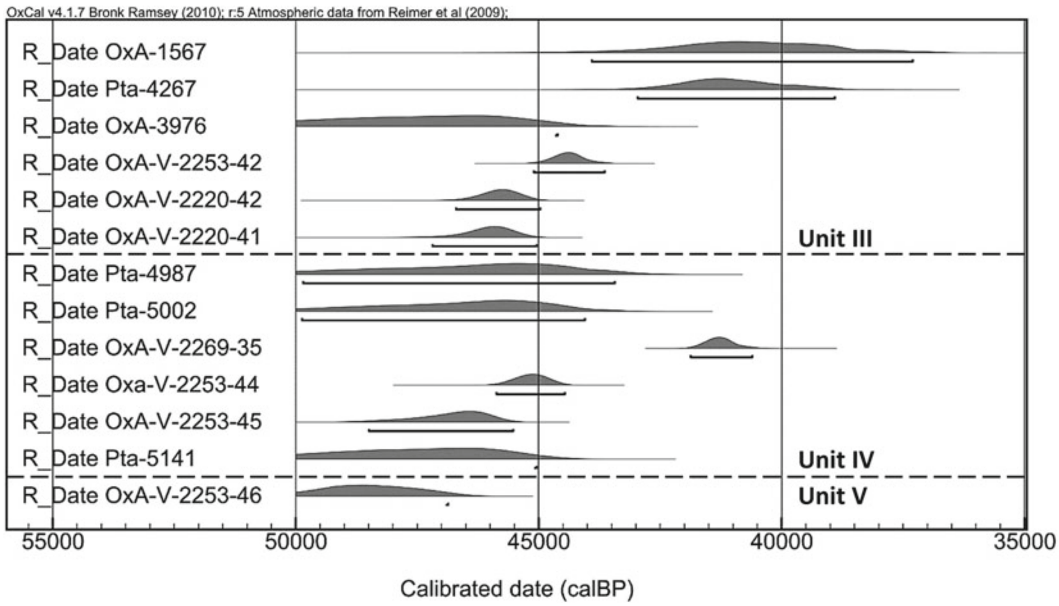


Fig. 3.12 Calibrated ages, calculated with OxCal 4.1 (Bronk Ramsey 2009) and IntCal09 (Reimer et al. 2009), of the finite ABA charcoal dates reported by Bar-Yosef et al. (1996) and Rebollo et al. (2011) for units III, IV and V of Kebara. At least two populations of dates are apparent. Based on regional chronostratigraphy, the Early Ahmarian in Units III-IV must be of the age indicated by the younger set of results; the older must reflect either the impact of contamination by ancient carbon or, most likely, the presence of an inherited charcoal component

only be decided on the basis of external consistency with regional patterns; and the set satisfying this criterion is the younger, not the older one.

Therefore, the corollary of validating all the ABA results for units III and IV is that, under Goldberg et al.'s (2007) rendition of the site's stratigraphy, the set of older dates must be a reflection of the presence in those units of inherited or intrusive Middle Paleolithic charcoal. Additionally, it remains conceivable that unit IV is a palimpsest where a hitherto unrecognized IUP/Emiran component is present alongside the Early Ahmarian, a possibility raised by Bar-Yosef et al.'s (1996, p. 304) remark that "the presence of a few Emireh points in Kebara (…) may indicate that this tool type, despite being considered the marker of the Transitional Industry (…), occurred in late Mousterian assemblages, derived from a disturbed Emiran layer to be found elsewhere in the chamber of Kebara, or that it lasted longer than the earliest Upper Paleolithic phase."

3.5.2 Protoaurignacian

Validating all of the ABA dates for Kebara and interpreting them in the framework of regional chronostratigraphy implies an age for the site's Early Ahmarian falling in the same time interval as that of the Protoaurignacian, thereby removing any rationale for making the emergence of the latter significantly earlier in the eastern part of its range. Where the western part is concerned, however, Hublin et al. (2012a) argue that the age recently obtained for the Protoaurignacian of Isturitz supports their claim that the Châtelperronian of the Grotte du Renne, St.-Césaire and Les Cottés overlaps in time with the earliest evidence for modern humans in central and southern France.

This claim is unsupported, as shown by Banks et al.'s (2013) Bayesian modeling of the chronology of the Protoaurignacian. The oldest of the lower limits of these authors' 95.4 % confidence intervals for Isturitz's modeled cal BP results is 41,840, and the corresponding youngest upper limit is 40,078; both are fully consistent with the 39.9–41.5 ka cal BP range modeled for the entire technocomplex. The same applies to Les Cottés, dates for which have since been published (Talamo et al. 2012). At this site, not only does the Protoaurignacian overlie the Châtelperronian, it is also separated from it by a 12 cm-thick sterile layer. This stratigraphic pattern should suffice to refute the notion that the two technocomplexes overlapped in time in this region of central France, but the dating results leave no doubt that no such overlap exists. In radiocarbon years BP, the six results obtained for the Protoaurignacian place it after 35,250 ± 280, while the six obtained for the Châtelperronian place it between 37,400 ± 500 and 42,410 ± 400. In calendar years, these Les Cottés results place the site's Protoaurignacian in the younger part of Banks et al.'s (2013) 39.9–41.5 ka cal BP interval for this culture as a whole, and the site's Châtelperronian in full contemporaneity with the ~41–45 ka cal BP interval obtained for the Grotte du Renne by Hublin et al. (2012a).

Additional Protoaurignacian results have now also been published for two Mediterranean sites, the Abric Romaní in Catalonia (Camps and Higham 2012; Vaquero and Carbonell 2012) and the Riparo Mocchi, in northern Italy (Douka et al. 2012). In both cases, the results fall well within the expected

39.9–41.5 ka cal BP interval and, where the Catalonian site is concerned, confirm Zilhão and d'Errico's (1999) interpretation of the previously available dates for level A, namely concerning the presence of a later, Gravettian component alongside that related to the Protoaurignacian.

3.5.3 Early Aurignacian

3.5.3.1 Geissenklösterle

Based on a large series of AMS radiocarbon dates for the stratigraphic sequence of the Geissenklösterle cave site, Conard and Bolus (2003) placed at ~40,000 radiocarbon years ago, significantly earlier than everywhere else in Europe, the beginnings of the Aurignacian in the Swabian Jura region of southwest Germany. Zilhão and d'Errico (2003) questioned this conclusion, arguing that:

(a) The site's Aurignacian sequence was a palimpsest of a number of occupations by both humans and cave bears, the latter being the most abundant taxon in the fauna from the corresponding levels (30.7 % by weight) (Münzel and Conard 2004, Table 1).
(b) Hahn's (1988) grouping of the Aurignacian deposits into only two "Archeological Horizons" (AH) was a useful data presentation tool but should not be misconstrued as real, observed stratigraphic units or as representing human occupation in only two moments of time.
(c) Given the slow sedimentation rate (~7.5 cm/millennium but, considering the volumetric weight of the artifactual and faunal components, much less in fact), coupled with cave bear activity and deformation of the deposits by periglacial phenomena (e.g., cryoturbation), significant post-depositional disturbance was probable and indeed confirmed by stone tool refitting.
(d) The numerous stratigraphic anomalies and the scatter apparent in the large set of radiocarbon dates then available primarily reflected this formation process.
(e) Such anomalies implied that not all dates obtained for a given level could be taken as accurately reflecting the age of the artifact assemblages therein, which themselves did not necessarily correspond to chronologically homogeneous assemblages.
(f) When only the dates on anthropically modified bones were considered, it was clear that the earliest Aurignacian occupation of this site did not predate ~36.5 ka ^{14}C BP and probably had taken place between 35 and 33 ka ^{14}C BP.

Based on a new set of 24 results obtained on ultrafiltered bone samples (Table 3.3), which show that many of the anomalies in the previously available corpus of dates derive from incomplete decontamination, Higham et al. (2012) concluded, however, that Conard and Bolus' (2003) original contention was supported: in the Swabian Jura, the Early Aurignacian would indeed have appeared very early, around 42,500 cal BP in fact. If correct, the implications of this conclusion are threefold:

(a) The Early Aurignacian or Aurignacian I and the Protoaurignacian would not be chronological phases of the Aurignacian technocomplex, with the former evolving out of the latter, but different cultures altogether.
(b) As the beginnings of the Early Aurignacian in different regions would seemingly extend over a considerable timespan, the lags would have to represent the difference between its time of emergence at a point of origin in Central Europe and the time of subsequent dispersals to other parts of the continent.
(c) The notion that the Protoaurignacian is a continent-wide stratigraphic marker and the earliest archeological culture of Europe with which modern humans can be associated would become untenable; not only would modern humans have spread into Europe much earlier than hitherto thought but they would also have done so via a number of different routes and under a diverse range of cultural guises.

Assessing the validity of these implications requires assessing the validity of the Bayesian model of the radiocarbon results upon which hangs the chronology proposed by Higham et al. for the Early Aurignacian of the Geissenklösterle. That model is based upon acceptance of Hahn's archeological horizons as a valid analytical framework for the discussion of the site's dating. As pointed out by Zilhão and d'Errico (2003, p. 75), this is erroneous and a fundamental flaw of Higham et al.'s study.

Are the "Archeological Horizons" Valid Bayesian Phases?

When items have the analytical significance of singular manifestations of a certain category of finds whose occurrence is common (e.g., when assessing the stratigraphic distribution of thick scrapers/cores), the archeological horizons framework applies regardless of moderate post-depositional disturbance and/or potential mixing. Hahn (1988) had estimated that about 7 % of the items in each horizon were displaced. In such a context, recovering five thick scrapers/cores in AH-II means that this artifact type was being discarded at the site during the time interval represented in that horizon, even though a certain probability exists that any of them, individually considered, could be an item displaced from AH-III, where 44 were recovered (data from Teyssandier 2003).

However, when items have meaning in and of themselves, as in the case of single bone fragments sampled for AMS radiocarbon dating, site formation processes such as those in operation at the Geissenklösterle imply that the archeological horizons framework is inappropriate. This is because dates on such samples represent the time of death of a single animal whose association with the artifacts found alongside has to be

Table 3.3 AMS radiocarbon dates on ultrafiltered bone samples from the Geissenklösterle published by Higham et al. (2012)

Sample name	Level	AH	OxA	Date BP	Species and material dated
GK 99 Ir 185	I-r	I	21,740	26,420 ± 230	*Ursus spelaeus* parietal cranium with cutmarks?
GK 130 It 328	I-t	I	21,660	27,960 ± 290	*Mammuthus primigenius* rib, impact marks
GK 26 Ia 18	I-a	I	21,739	28,600 ± 290	*Mammuthus primigenius* rib (?) cutmarked
GK 86 Ic 122	I-c	I	21,661	32,900 ± 450	*Rangifer tarandus,* metacarpal, impact mark
GK 33 IIa 80	II-a	II	21,737	35,700 ± 650	cf. *Rangifer tarandus*
GK IIa 131	II-a	II	21,656	33,000 ± 500	*Equus ferus*, scapula
GK 58 IIb 246	II-b	II	21,724	33,950 ± 550	*Mammuthus primigenius* rib fragment with impact point
GK 57 IIb 706	II-b	II	21,727	34,100 ± 550	*Ursus spelaeus*, rib fragment, with a cutmark
GK 67 IIb 931	II-b	II	21,742	34,800 ± 600	*Equus ferus*, humerus
GK IIb 143	II-b	II	21,738	34,900 ± 600	*Equus ferus,* humerus (retoucher marks inferred)
GK 55 IId 319	II-d	III	21,726	34,200 ± 550	*Equus ferus*, humerus (retoucher)
GK 77 III 627	III	III	21,659	35,050 ± 600	*Rangifer tarandus*, tibia, impact mark
GK 77 III 641	III	III	21,744	36,850 ± 750	*Coelodonta antiquitatus* humerus no cutmarks
GK 86 III 294	III	III	21,725	37,400 ± 800	Large unidentified mammal rib fragment (cf *Coelodonta antiquitatus/Mammuthus primigenius)*
GK 66 III 1144	III	III	21,722	38,900 ± 1,000	*Equus ferus*, distal femur
GK 66 IIIa 1073	III-a	III	21,745	36,650 ± 750	*Rangifer tarandus,* tibia, impact marks
GK 67 IIIa 1453	III-a	III	21,746	36,850 ± 800	*Rangifer tarandus,* tibia with cutmarks
GK 67 IIIb 1655	III-b	III	21,743	36,100 ± 700	*Rangifer tarandus*, tibia with impact and cutmarks
GK 69 IIIb 958	III-b	III	21,723	37,800 ± 900	Artiodactyl limb bone fragment
GK 57 IIIb 1238	III-b	III	21,721	37,300 ± 800	cf. *Coelodonta antiquitatus/Mammuthus primigenius* bone fragment with scrape marks, i.e., humanly modified bone.
GK 57 IIIc 2389	III-c	III	21,658	38,300 ± 900	*Capra ibex*, left tibia, no human modification
GK 57 IIIc 2430	III-c	III	21,657	39,400 ± 1,100	*Cervus elaphus*, tibia, no human modification
GK 78 IV 1495	IV	IV	21,720	35,500 ± 650	cf. *Ursus spelaeus* juvenile shaft fragment. Possible impact.
GK 48 VII 456	VII	VII	21,741	48,600 ± 3,200	*Capra ibex*, phalanx I, which articulates with metataurus. No clear cutmarks although two are inferred.

AH denotes "Archeological Horizon"

treated, if post-depositional disturbance is significant, as an open issue. In that case, the correct approach is to assess the samples independently of their context and as representing a separate category of stratigraphic information, one where time ordering comes from their intrinsic properties (their radiocarbon ages), not from their extrinsic ones (their strata of provenience or their putative archeological associations).

Higham et al. disagree with Zilhão and d'Errico's (2003) position on the grounds that subsequent excavation and stone tool refitting work suggested that Hahn's (1988) estimates of stratigraphic disturbance were exaggerated. They argue that this new work, coupled with micromorphological analysis (Conard et al. 2006), showed that the apparent disturbance pattern diagnosed by Hahn is caused by the fuzziness of level boundaries, and consequent "excavation error," rather than by the vertical displacement of objects.

To suggest that post-depositional disturbance is not a significant issue in the case of a ~50 cm-thick sequence accumulated in a periglacial environment, over some ten millennia, and under the impact of continued human or cave bear activity, is unrealistic to begin with. In fact, it is also contradicted by refitting, which documents numerous inter-level links, often scattered across the entire sequence—not just across the boundaries of adjacent levels, as the excavation error model implies. Hahn's (1988) data already showed that more refits existed between the levels grouped to form his upper Aurignacian horizon AH-II (II-n, II-a and II-b) and those forming his lower Aurignacian horizon AH-III (II-d, III, III-a and III-b) than within AH-II itself. Teyssandier's (2003) re-analysis of the primary data, while illustrating a number of cases where post-depositional displacement is limited, also provided several instances of the opposite case, namely the detailed, telltale example of the A1 refitting unit (a block of high-quality, easily recognizable red radiolarite), whose 44 elements are spread over 14 m^2 and all the way from II-a at the top of the sequence to III-a at its base (Table 3.4). The only conclusion that can be drawn from this refitting work is, therefore, that the interface between levels II-b and II-d cannot be used as a discrete boundary separating an "upper" from a "lower" Aurignacian. In order to understand what has gone on at the site, the distributions of significant items have to be seen relative to each other and across the entire sequence taken as a single, continuous analytical framework (Fig. 3.13).

More importantly, Higham et al.'s excavation error argument is an obvious non-sequitur. Regardless of whether

Table 3.4 Horizontal and vertical distribution of the individual items in Geissenklösterle refitting unit A1 (Teyssandier 2003: Table 11)

	Archeological level							
Square	IIIa	III	IId	IIb	IIa	II?	ind.	Total
15	–	1	–	–	–	–	–	1
25	–	–	–	1	–	–	–	1
26	–	–	–	1	1	–	–	2
37	–	2	–	1	–	4	–	7
38	–	4	2	2	–	–	–	8
45	–	–	–	1	1	–	–	2
47	–	1	1	1	–	–	–	3
48	–	3	2	1	–	–	–	6
49	–	1	–	–	–	1	–	2
56	2	–	2	1	–	–	–	5
57	1	–	–	–	–	–	–	1
58	–	–	1	–	–	–	–	1
59	–	1	–	–	–	–	–	1
66	1	1	–	–	–	–	–	2
ind.	–	–	1	–		–	1	2
Total	4	14	9	9	2	5	1	44

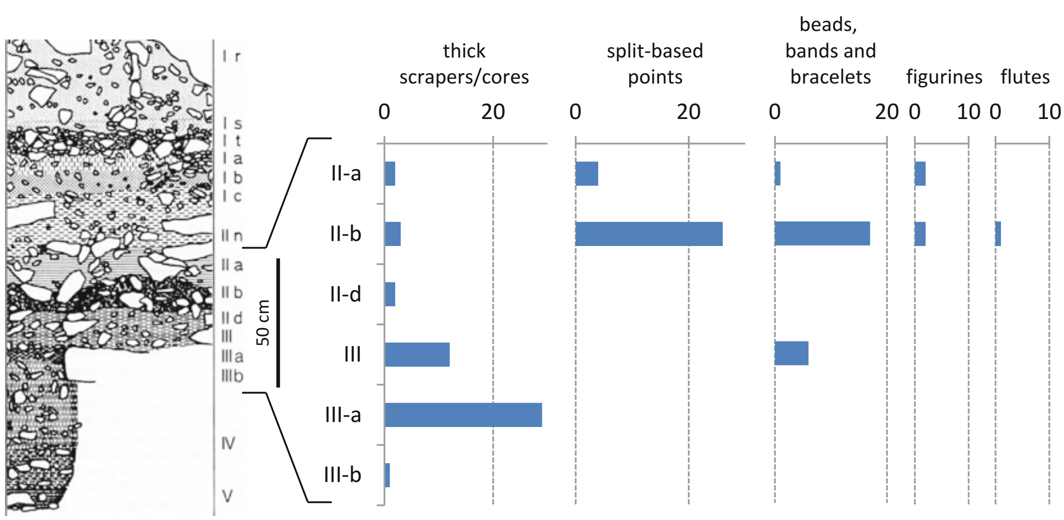


Fig. 3.13 Geissenklösterle. Vertical distribution of finds diagnostic of the Aurignacian I, of mobiliary art items, and of musical instruments across the levels assigned to the Aurignacian by Hahn (1988; data from Teyssandier 2003 and Teyssandier and Liolios 2003). Note that Higham et al. (2012) claim a very early age for the site's Aurignacian I based on samples from Archeological Horizon III but that split-based bone points, the index fossil of the Aurignacian I, were only present in levels (II-a and II-b) assigned to the site's Archeological Horizon II above

assignment of a given item to a level other than that where it originally lay results from natural (disturbance) or human (error) agency, the implication is the same—if the agent is observed to have had a significant impact, reasoning by association is of limited value and, in the best of cases, needs to be qualified. Additionally, while correctly pointing out that excavation error implies that the finds assigned to each of Hahn's fine stratigraphic subdivisions cannot be taken as closed assemblages, Higham et al. fail to consider that boundary fuzziness must also imply that Hahn's two archeological horizons, or even the Aurignacian package as a whole, cannot be taken as closed assemblages either: whether by disturbance or error, stratigraphic misplacement of finds is a problem that must then concern not only the *subdivisions within* the Aurignacian but also the *divisions between* the Aurignacian and adjacent units, on one hand, and Hahn's Aurignacian horizons I and II, on the other.

In such a context, for instance, there is no reason to assume that an item recovered in III-b, at the base of AH-III, is more likely to be contemporaneous with an item from II-d, at the top of AH-III but separated from III-b by the ~15 cm of deposits forming levels III and III-a, than with an item from immediately underlying level III-c. In short, for dating, excavation error has the same implication as post-depositional

Table 3.5 Results of a sample significance test (Ward and Wilson 1978, Case 1) carried out with Calib 6.1 (Stuiver and Reimer 1993) on the samples grouped under the AH-II and AH-III phases of Higham et al.'s (2012) Bayesian model

Phase	Test statistic t	χ^2 (0.05)	Degrees of freedom	Significantly distinct at the 95.4 % level
AH-II	13.60796	11.1	5	Yes
AH-III	45.16257	19.7	11	Yes

disturbance: it precludes the discretization of the deposits into phases, making Higham et al.'s Bayesian model logically invalid, and implies that the distribution of the dated samples must be treated as a stratigraphic continuum, in much the same way as that of the bone and stone tool index fossils.

Vertical Distribution of Index Fossils and Dating Samples

The material cultural categories found at the site that are representative of the Aurignacian I as known from a large number of well-stratified localities from southwestern France (namely, the rock-shelters of Pataud and Castanet; Higham et al. 2011d; White et al. 2012) are: split-based bone/antler points; ivory beads, bands and bracelets; and thick scrapers/cores. The distributions of such items by level (Fig. 3.13) show that they were recovered between II-b and III-a, with a trickle of finds spilling over to II-a above and III-b below; elements of clustering also exist, ones whose explanation likely relates to spatial patterning in both human activity and post-depositional disturbance. These distributions also indicate that the four sculpted figurines and the flute from levels II-a and II-b belong to a post-Aurignacian I occupation of the site, as one might suspect on the basis of the radiocarbon dates associated with similar material at the neighboring sites of Hohle Fels, Vogelherd and Hohlenstein-Stadel (Zilhão 2007).

It is only against this background that meaning can be assigned to Higham et al.'s new radiocarbon dates, as otherwise indicated by the observation that the results included in each of the Aurignacian phases (AH-III and AH-II) of their Bayesian model are statistically distinct ones (Table 3.5). Given the evidence for a number of different human and animal occupation episodes to be represented within each of those phases, this is hardly surprising; if the archeology indicates that the assemblages are chronologically heterogeneous, it is to be expected that their sampling for dating will eventually return heterogeneous results. The really important point to bear in mind, however, is that seven out of the twelve results obtained for the levels that yielded the diagnostic finds (II-b to III-b) fall fully in, or significantly overlap with, the time range of the Aurignacian I—the 39.8–37.9 ka cal BP interval, based on the European-wide database of radiocarbon results analyzed by Banks et al. (2013) (Fig. 3.14).

Of the 24 samples dated by Higham et al., only 15 are of anthropically modified bone. Of these, four are qualified as possible, inferred or questionable, and only eight are on taxa that we can safely assume to have been hunted (horse, reindeer and ibex). This point is important because the anthropically modified samples of wooly rhino and mammoth may reflect subfossil (i.e., radiometrically older) raw-material collected as site furniture or for the manufacture of bone/ivory tools, an activity that, as Higham et al. emphasize, was very important in AH-III. The same conceivably applies to the modified cave bear samples, although these could also reflect episodic interaction with the carnivores owning the site at times when humans were infrequent in the landscape; even in that case, however, they would by definition be indicative of intervals during which no artifacts related to human residence were discarded in the cave.

Bearing this in mind, let us take the bone samples that are secure indicators of contemporaneous human activity as proxies for the time of occupation, regardless of stratigraphic provenience and putative artifact associations but assuming the accuracy of the results obtained for them. When this is done (Fig. 3.15), we obtain a very clear pattern, one that, although somewhat blurred by the potential sources of noise, is already apparent in the overall plot: at the time of the Middle-to-Upper Paleolithic transition, human activity at the Geissenklösterle occurred in three distinct time intervals, first ~41.5 ka, then ~40.0 ka, and finally ~37.5 ka cal BP (an earlier Mousterian occupation of level VII is documented by a possibly cut-marked ibex bone dated to beyond the reach of current calibration tools and, consequently, not represented in Fig. 3.14).

Interestingly, this restricted set of results is in full stratigraphic order: the three samples documenting the intermediate episode come from levels II-d, II-b and III, the sample documenting the younger episode comes from level I-c above, and the three samples documenting the older episode come from levels III-a and III-b below. This pattern shows that, despite the disturbance, the Geissenklösterle sequence preserves the original stratigraphic structure to a considerable extent. Within limits, it can thus be used to assess issues of dating and diachronic change, but only in terms of the relative stratigraphy of individual find categories or type fossils (e.g., their order of appearance, or their frequency change through time). Assigning an absolute age to the points in the sequence where one can see phenomena of emergence or change, however, requires an external referent, which, in this case, can only be the European-wide chronostratigraphy of the Aurignacian.

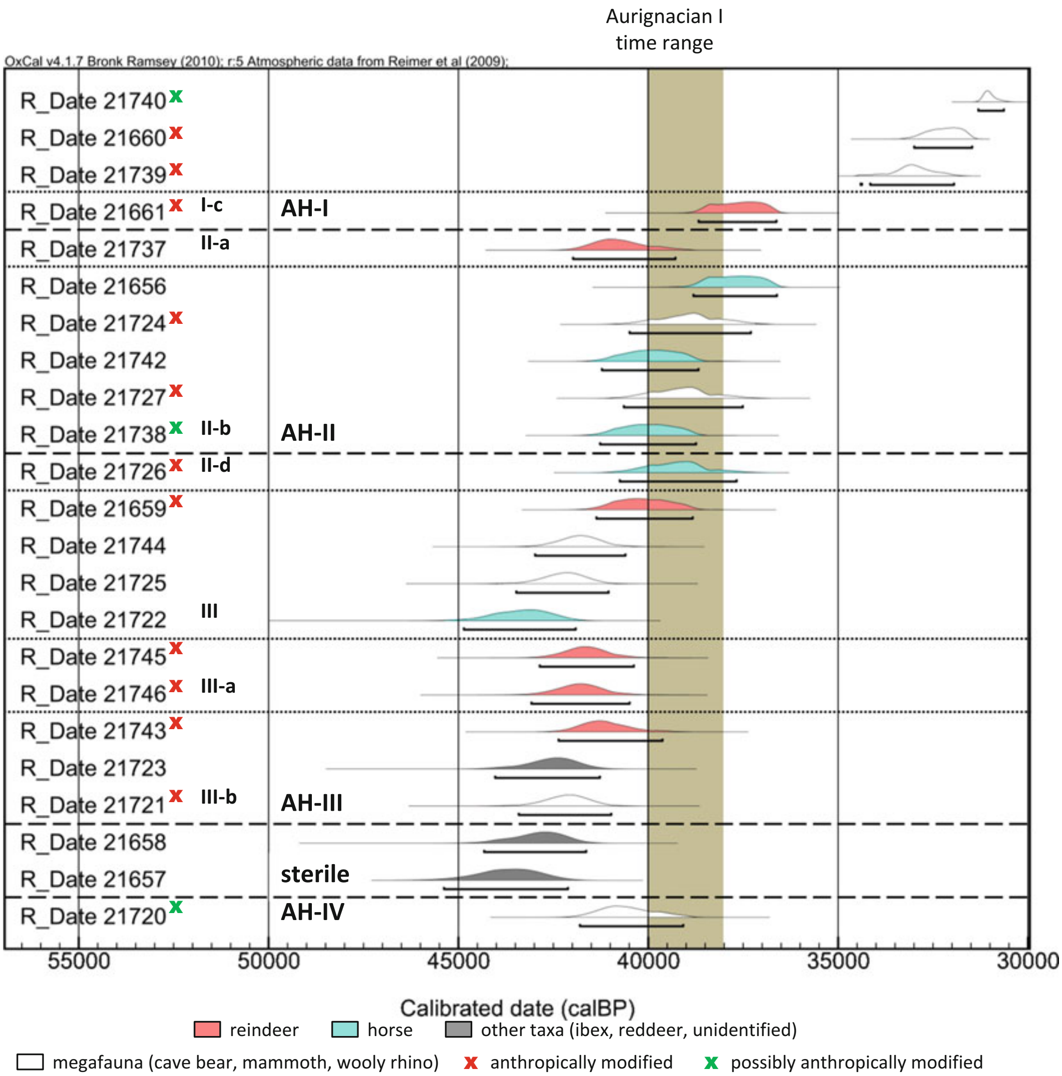


Fig. 3.14 Calibrated ages, calculated with OxCal 4.1 (Bronk Ramsey 2009) and IntCal09 (Reimer et al. 2009), for the ultrafiltered bone dates reported by Higham et al. 2012 for the Geissenklösterle. The result for an ibex bone with inferred cutmarks from level VII falls outside the calibration curve and is not plotted

An Alternative Interpretation of the Geissenklösterle Stratigraphy

In this framework, there can be little question that the intermediate and younger of the three episodes indicated by the set of anthropically modified horse and reindeer bone samples are local manifestations of the Aurignacian I and Aurignacian II, respectively. Where the younger episode is concerned, this conclusion is further strengthened by the recent identification of diagnostic Roc-de-Combe bladelets among the small finds from sieving (Moreau 2009, 2012). The remaining issue is how to interpret the older episode.

On the basis of the presence of a significant number of thick scrapers/cores in one of the levels (III-a) where the corresponding samples come from, we could conclude, alongside Higham et al., that the older, ~41.5 ka cal BP episode is also related to the Aurignacian I. If so, one would have to concur with them that the Aurignacian I emerged in the Swabian Jura earlier than elsewhere in Europe (even if only by one and a half instead of two and a half millennia), and, hence, that it should be assigned the status of a distinct culture instead of a chronological phase. However, such a culturally separate manifestation of modern human immigration would still be no earlier than that represented by the Protoaurignacian. Therefore, even such an interpretative scenario would represent no challenge to the time horizon (~36.5 ka ^{14}C BP, ~41.5 ka cal BP) postulated by Zilhão and d'Errico (1999) for the dispersal of modern humans into Europe.

However, another explanation can be proposed that is consistent with both the evidence from the site and continent-wide chronostratigraphic patterns and, therefore, ought to be considered the parsimonious alternative. Considering excavation error and post-depositional displacement, it is quite

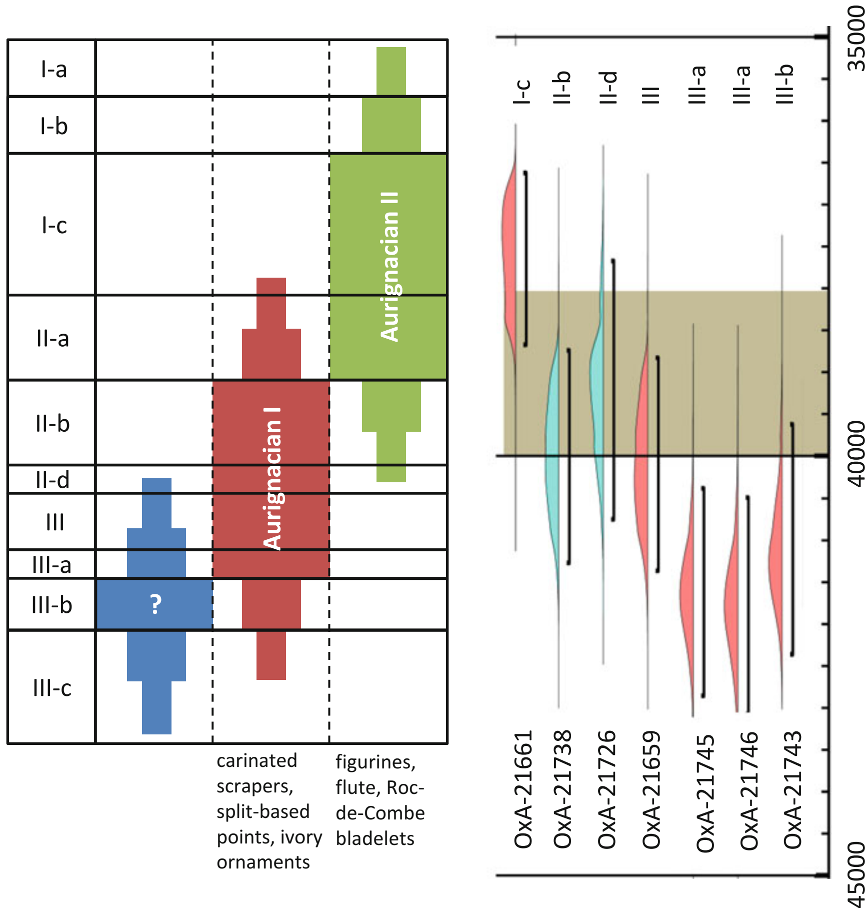


Fig. 3.15 Geissenklösterle. An alternative reading of the stratigraphy: instead of Higham et al.'s two well delimited phases, based on Hahn's (1988) less rigid concept of two horizons, at least three periods of occupation with fuzzy boundaries are proposed; level II-b is considered to belong in the Aurignacian I and, following Moreau (2009, 2010), level I-c subsumes level II-n and is considered to be part of the Aurignacian sequence. A three-period pattern is also apparent when considering only the samples from game taxa (horse and reindeer) with possible or secure anthropic modification. The relative thickness of the stratigraphic subdivisions in the model is derived from the published profiles. The dating evidence, given in cal BP years, consists of the results obtained on samples of anthropically modified game taxa, extracted from Fig. 3.14 (with the same sample color codes, and with the same time band to indicate the chronostratigraphic slot of the Aurignacian I)

possible that, of the three anthropically modified reindeer samples that were dated to ~41.5 ka cal BP, the two labeled III-a were originally laid down with the material recovered in III-b, from where comes the other sample. That this is entirely conceivable is supported by two lines of evidence: firstly, statistically identical results were obtained for another two samples from III-b (Fig. 3.14); secondly, III-a is a very thin, ~5 cm-thick lens of material, where, given the general issue of boundary fuzziness, incorrect assignment and vertical displacement (even of very limited scope) would be even more of a problem than at other points in the sequence.

If the ~41.5 ka cal BP human occupation of the Geissenklösterle does not relate to the Aurignacian I, where do its cultural affinities lie? Based on the then available results, Zilhão and d'Errico (2003) had proposed the same three-phase model revealed by proper interpretation of the new ones, and suggested two possibilities for the earlier phase. The first was that of a short-lived, logistical expedition by Protoaurignacian people leaving behind no diagnostic tools (or ones that remain to be identified among the excavation's unsorted water-sieved sediments; cf. Moreau 2009, 2010, 2012)—a possibility suggested by the contemporaneous presence of such people further downstream, in the middle and lower Danube basin (e.g., at Krems-Hundsteig, in Austria, or Tincova, in Romania). The second possibility was that of an expedition of a similar kind but related to the Altmühlian and reflecting the activity of the latest Neandertal inhabitants of the region. The alternative remained undecided for Zilhão and d'Errico (2003), and recent work has not changed our understanding of level III-b, which only yielded four retouched tools: a carinated scraper/core related to the overlying Aurignacian I, and three that are undiagnostic (two blades with use wear and a truncated blade; Teyssandier and Liolios 2003). Therefore, the prudent approach continues to be that of treating the cultural affinities of the ~41.5 ka cal BP human occupation of the Geissenklösterle as an open issue.

A corollary of the evidence reviewed above is that Hahn's (1988) organization of the Aurignacian stratigraphy of the Geissenklösterle into two archeological horizons has outlived its usefulness. For the future, grouping the different layers recognized during excavation along the lines of the three phase model suggested here (cf. Fig. 3.15) seems to be a more promising way of making progress in sorting out the different issues of association raised by the site's late Middle and early Upper Paleolithic levels. Provided, of course, that the continuous rather than discrete nature of the distributions and the relative rather than absolute nature of the boundaries between level groupings are duly considered in the process.

Further support to this contention comes from the fact that level I-c should be assigned to the Aurignacian instead of the Gravettian, given Moreau's (2009, pp. 195–210; 2010) convincing arguments to that effect: sedimentological continuity with the very poor Aurignacian level II-n below (cf. Fig. 3.13); raw-material economy, namely the preference for *Bohnerzhornstein* over radiolarite among retouched tools, as in the site's AH-II Aurignacian horizon and the reverse of the Gravettian pattern; typology, namely the dominance of scrapers over burins and the presence of typical nosed scrapers; technology, namely the fact that bladelet tool blanks were extracted from "burin"-type cores; and refitting, namely of a burin from I-c with two burin spalls from II-b. Except for a microgravette fragment made of radiolarite and deemed to be intrusive from the overlying Gravettian, the kinds of backed microliths present in I-c also exist in the AH-II Aurignacian horizon, where they are found in association with characteristic Dufour bladelets made of the same *Bohnerzhornstein*. Such a co-occurrence of bladelets trimmed in both Dufour and backing fashion is documented in Evolved and especially Later Aurignacian (Aurignacian III-IV) contexts from elsewhere in Europe (e.g., at the Portuguese site of Pego do Diabo; Zilhão et al. 2010b; see also Pesesse 2008, 2010). This evidence indicates that the affinities of level I-c lie indeed with the Aurignacian, in agreement with the 32,900 ± 450 ^{14}C BP result obtained for this level by Higham et al., which falls fully within the time range of the Aurignacian II.

3.5.3.2 Willendorf II

The other Central European site where a precocious occurrence of the Aurignacian I has been claimed is Willendorf II, in Austria. As most recently argued by Nigst and Haesaerts (2012), assignment of layer 3 of this locality to the Early Aurignacian would be supported by technological analysis of a hitherto undescribed set of hundreds of lithic artifacts from the early twentieth-century excavations. At the same time, two AMS dates in the ~38–39 ka ^{14}C BP range would indicate that the previously available conventional date in the ~34 ka ^{14}C BP range is an underestimate of the level's true age. Finally, refitting work would support the integrity of the level, i.e., a stratigraphical and functional relationship between the lithics and the dated charcoal, closing the case for the Aurignacian I to be five millennia older in Lower Austria than anywhere else in Europe.

That diagnostic material of clear Aurignacian affinities—namely, carinated and nosed scrapers/cores—is present in layer 3 of Willendorf II has also been suggested by others (e.g., Hahn 1977; Teyssandier 2003) and will not be disputed here. There is also no reason to question the accuracy of the new AMS radiocarbon dating results. The leap of faith made by Nigst and Haesaerts (2012) is to infer from this evidence that layer 3 is chronologically homogeneous and that *all* of the lithics recovered therein relate to the Aurignacian I and to the charcoal pieces dated to ~38–39 ka ^{14}C BP. However, that is not necessarily the case.

The small assemblage of formal retouched tools (35 in total) in layer 3 includes not only five carinated and four nosed scrapers/cores but also two sidescrapers and 12 "laterally retouched blanks" among which, from the illustrations supplied, a number could also correspond to sidescraper fragments. If at all present, sidescrapers, however, are a rare occurrence in Aurignacian I assemblages. For instance, none exist in either the AH-II or AH-III horizons of the Geissenklösterle, and very few in the reference sequence of the Abri Pataud, France (layers 9–14; Table 3.6), where they are absent from most levels and represent, in total, 0.47 % of the formal tools, contra a minimum of 5.71 % in layer 3 of Willendorf II. With present evidence, it is therefore conceivable that at least two different components are present in this layer, one of which is of Mousterian or Upper Paleolithic but pre-Aurignacian (e.g., Szeletian, Altmühlian or Bohunician) affinities, and that the radiocarbon dates are all accurate and reflect this cultural heterogeneity.

This possibility is contradicted neither by the fact that refits could be carried out in the collection from the old excavations, nor by eventual refits to be obtained in the future between material in that collection and material from the new excavations being carried out at the site since 2006 (Nigst et al. 2008). In a classic paper whose key points are all too often overlooked, Bordes (1980) discussed the applicability, and limits, of refitting for the assessment of issues of contemporaneity within potentially heterogeneous assemblages. To illustrate the point, Bordes provided an example from near the Billabong station in Western Australia: "Tools undoubtedly belonging to the base of layer 2 of the local sequence, uncovered by deflation and dating from the beginning of our era, and fragments of motorbikes, cars, etc., are scattered on the same surface. No doubt that, with patience, it would be possible to refit aboriginal flakes between them, and car fragments between them. Yet, 2,000 years separate the two

Table 3.6 The relative frequency of sidescrapers in the Aurignacian I levels of the AbriPataud (data from Chiotti 1999)

Layer	Total tools	Sidescrapers	%
9 and 9/10	27	–	–
10	59	–	–
11	976	8	0.82
12	387	1	0.26
13	83	–	–
14	177	–	–
TOTAL	1,923	9	0.47

series." A similar time span could well be represented in layer 3 of Willendorf II, with the sidescrapers representing displaced material from an earlier period and the blade production refits and carinated cores representing a later one.

Even if the stone tool assemblage is eventually shown to be homogeneous and Aurignacian, the case for the occurrence to be a precocious one would still require demonstration of two additional points: firstly, that the age of all of the associated charcoal is indeed ~38–39 ka ^{14}C BP; secondly, that such charcoal is functionally related to the stone tools instead of representing an inherited component of the deposit. Where this latter point is concerned, I have laid out in a preceding section the case for the presence of a significant inherited component to be the most likely explanation for the very old dates obtained for samples from the Early Ahmarian levels of Kebara. I had previously made a similar case for the Austrian site: "At Willendorf II, Austria, the evidence comes from level 3, which yielded a small assemblage of artifacts in secondary position sitting on an eroded surface that yielded soliflucted charcoal dated to ca. 43 kyr cal BP. However, as recently acknowledged by the site's researchers, 'dating small charcoal fragments dispersed in soliflucted layers must be avoided' because of the 'lateral supply of older charcoal fragments.' Such a supply clearly explains the anomalous results, which simply provide a *terminus post quem* for the lithics, the affinities of which lie with the Aurignacian I" (Zilhão 2006a, p. 187). Nigst and Haeserts (2012, p. 598) have misunderstood this argument as one for the layer 3 charcoal to represent material displaced from underlying units. The potential problem, however, is one of lateral (not vertical) supply of older material, i.e., a mechanism of progradation whereby, downslope, a level formed subsequent to the occurrence of an erosional truncation will inevitably be a palimpsest mixing new sediment inputs (e.g., windblown loess) with components derived by gravity or solifluction from pre-existing, upslope deposits.

From the published descriptions and illustrations of the geometry of layer 3 of Willendorf II (e.g., Nigst et al. 2008, Fig. 5), there can be little doubt that the archeology therein is not in primary position (as otherwise indicated by the absence of features such as hearths), and that the impact of progradation processes on the association between lithics and charcoal must be duly considered in its interpretation. In such circumstances, the apparent, anomalously early age of the lithics of Early Aurignacian affinities from layer 3 of Willendorf II must be treated as just that: an anomaly for which no definitive explanation exists at present but upon which it would be foolhardy to hang any model of population dispersal or replacement at the time of the Middle-to-Upper Paleolithic transition in Central Europe.

3.6 Discussion

The preceding discussion of the key sites and finds can be briefly summarized as follows:

(a) The deposit containing the St.-Césaire partial skeleton also yielded Middle Paleolithic artifacts and its genesis was complex, but direct dating rejects assignment of the skeleton to the Mousterian and stratigraphic context precludes assigning it to the Protoaurignacian. Association of the fossil with the diagnostic Châtelperronian lithics found alongside remains the parsimonious reading of the evidence. At the Grotte du Renne, a Neandertal authorship of the Châtelperronian (including, in this case, abundant, evidently symbolic material culture) is also supported by the associated human fossils, while spatial distributions and radiocarbon dating corroborate the largely intact nature of the stratigraphic sequence.

(b) Given sample size and the documented overlaps in dental anatomy between late Neandertals and early modern humans, the nature of the Kent's Cavern and Cavallo fossils is an open issue, as is their true age, so the Oase 1 mandible and Oase 2 cranium remain Europe's oldest modern humans. Oase 1 is directly dated to ~40 ka cal BP, with the associated uncertainty implying assignment to either the Protoaurignacian or the Aurignacian I. Speculations to the effect that the Uluzzian and the coeval, so-called transitional Upper Paleolithic cultures of Europe, including the Châtelperronian, could have been the work of modern humans, are unsupported.

(c) Boundary fuzziness, post-depositional displacement of finds and palimpsest formation preclude the discretization of the Geissenklösterle sequence into Bayesian phases and command that only anthropically modified samples of game taxa be used as proxies for human activity at the site. When this is done, there is no disagreement between the age of the levels that yielded finds diagnostic of the Aurignacian I and the chronology of the latter everywhere else in Europe. A precocious presence of Aurignacian I modern humans in Central Europe is not supported by layer 3 of Willendorf II either, as this layer is in secondary position and potentially heterogeneous in terms of both its stone tool and charcoal components.

(d) The source of Europe's first modern human immigrants is agreed to lie in western Asia and the Early Ahmarian. Claims for an emergence of the latter prior to 46,000 calendar years ago are based on the dating of samples from Kebara that reflect the presence of inherited Middle Paleolithic charcoal in the Early Ahmarian strata. A second population of age measurements from the same stratigraphic units dates the technocomplex to some five millennia later on, at about the same time as the Protoaurignacian and in agreement with regional chronostratigraphic patterns.

(e) As documented by the dates obtained for Les Cottés and Grotte du Renne, the Châtelperronian emerged in central and northern France at least four millennia before the Protoaurignacian is first documented in regions to the south. Given the association with large numbers of ornaments, bone tools and pigments, and this from its very beginnings in level X of the Grotte du Renne, the emergence of the Châtelperronian cannot possibly be the reflection of an immediate cultural influence exerted by (non-existent) early modern human neighbors, and must result instead from the action of cultural processes indigenous to the Neandertal populations of western Europe.

The archeological and radiometric dating evidence accumulated over the last 15 years therefore fails to reject the chronological model put forward by d'Errico et al. (1998) and Zilhão and d'Errico (1999). This new evidence remains entirely consistent with the notion that, in Europe, the onset of the processes of population interaction that led to the eventual assimilation of the Neandertals broadly coincides with the emergence of the Protoaurignacian ~36.5 ka ^{14}C BP (~41.5 ka cal BP). Consequently, no reason exists to question the corresponding implication that Neandertals were the makers of the material manifestations of symbolic or artistic behavior seen in the archeological record of the continent prior to that date.

A first corollary of these chronological patterns is that symbolism and "anatomical modernity" cannot be construed as causally related (d'Errico 2003; Zilhão 2006a, 2007; Conard 2008). This was to be expected, given the paleontological and genetics evidence for significant admixture and, therefore, species sameness, between Neandertals and early moderns. It is also something that should have been realized ever since ornaments were uncovered in the Aterian culture of North Africa, which, in this time range (~100 ka BP), was inhabited by people who, while not Neandertal, were not fully anatomically modern either—as apparent, namely, in the cranial, mandibular and dental anatomy of the Dar-es-Soltan fossils (Klein 1992; Wolpoff 2002; Trinkaus 2005; Bouzouggar et al. 2007; Bouzouggar and Barton 2012; Hublin et al. 2012b).

A second corollary is that, given the limited temporal resolution of stratigraphic sequences and the relatively poor precision of the radiometric techniques that can be applied to the dating of sites and fossils from this time range, the "Who Made What" question for the material culture of the couple of millennia bracketing the ~36.5 ^{14}C/41.5 cal ka BP interval, even if relevant, may not be answerable. In fact, that Assimilation occurred implies processes of gene flow and population dispersal (of which the Assimilation process probably represents no more than a step-up in frequency and intensification) that must have been in operation before, even if at a smaller scale. If so, then cultural exchange and diffusion hitch-hiking such biological interaction and operating in both directions must also have been in place well before the crossing of the critical threshold, that is, well before the replacement of the Neandertal by the early modern human phenotype became visibly and unambiguously apparent in the human paleontological record of western Eurasia.

In the context of these chronological patterns, it is useful to elaborate on the potential implications of the cave art dating results recently obtained by Pike et al. (2012) with the U-series method. That Neandertals are likely to be the makers of the red disks from the Panel of Hands at El Castillo (Fig. 3.16) follows from the fact that one such disk is covered by calcite dated to 40.8–42.0 ka (95.4 % probability interval), while the corresponding calendar age interval for the Oase 1 mandible is 38.8–42.0 ka, and Banks et al.'s (2013) modeled calendar range for the earliest conceivable archeological proxy for European early moderns, the Protoaurignacian, is 39.9–41.5 ka. These ranges overlap in the 40.8–41.5 ka interval but we must bear in mind that, at El Castillo, the date represents a minimum age for the underlying art, not its real, if imprecise age, as is the case with the dates for Oase 1 and the Protoaurignacian.

This means that the dated El Castillo art could have been made in the 42nd calendar millennium BP and, therefore, conceivably, by Europe's earliest modern human populations, only if the length of time separating its execution from the growth of the overlying calcite was a short one. This is unlikely to be the case, however, because Pike et al. followed a sampling protocol whereby, in order to avoid contamination by detrital thorium from the cave wall or from pigments in the paintings, the first calcite to grow over the art was not collected. Subsequent work at the Panel of Hands, carried out in October 2012, showed that, in fact, sufficient material remained between the red disk and the base of the previously measured calcite, and an additional sample was collected. So, the execution of that symbol and the published calcite date

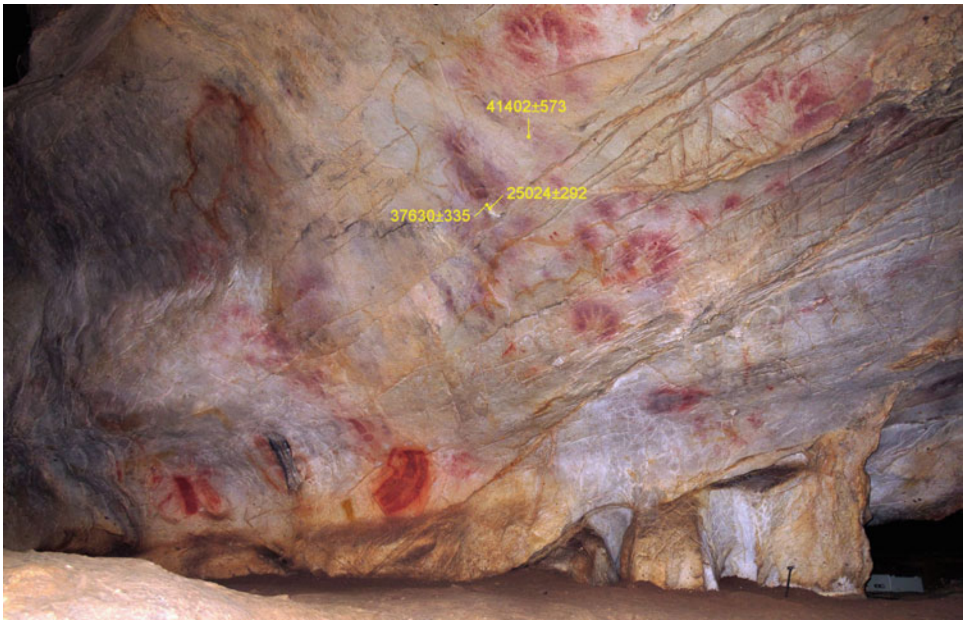


Fig. 3.16 El Castillo. The Panel of Hands, with indication of the location and age (95.4 % probability intervals) of the calcite samples dated by Pike et al. (2012)

are separated by an interval of time of unknown length during which the first calcite formed; the art is therefore older than calcite that is itself more than ~41.4 thousands of years old.

The wider implication of these observations becomes apparent if we consider that >50 % of the minimum ages reported by Pike et al. for 11 Paleolithic cave art sites in northern Spain are ≤10,000 years, while, on stylistical grounds (validated by previous radiocarbon dating and the U-series results), the age of the motifs under the dated calcite is in the range of 20,000 years or more. The probability is very high, therefore, that, at El Castillo, the red disk under the dated calcite was executed in the 43rd millennium or before, i.e., at a time when Europe was still a fully Neandertal continent. Moreover, late Neandertal authorship of such geometric signs (and, perhaps, of the associated hand stencils) is consistent with what we know of their symbolic material culture, namely, at the Grotte du Renne, the decoration of bone awls: of the 52 recovered in the site's Châtelperronian levels, more than a third are marked along the edges with non-utilitarian, regularly arranged incisions (d'Errico 2003; Caron et al. 2011).

Beyond their significance for controversies surrounding the cognition and behavior of the Neandertals and their taxonomic status, Pike et al.'s U-series dates also suggest that the earliest forms of art may well have been non-figurative. Traditionally, the birth of art has been equated with the emergence of the naturalistic animal representations that are so emblematic of the Paleolithic. This is understandable, given that, hitherto, the dating of parietal art has relied heavily on stylistical comparison with mobiliary art items recovered in stratified archeological contexts. However, while the conventions used to represent animals can and did change over time, the same does not necessarily apply to such universals as geometric shapes or the human hand. It has been largely assumed that motifs of these kinds are of the same age as the animals found on the same walls and that dating the animals also dates the signs and the other symbols, but Pike et al.'s results show the assumption to be unwarranted.

If, in Europe, the evidence for personal ornaments and heavy use of pigments correlates from the very (Neandertal) beginnings with the presence of rock art alongside, then we should expect the same to be true for Africa and Asia. Thus, the ultimate implication of the El Castillo results may well be that the graphic tradition revealed in the geometric decoration of the ostrich eggshell containers from the 60,000 year-old Howiesons Poort levels of Diepkloof rock-shelter, in South Africa (Texier et al. 2010), is likely to stand for a behavior that encompassed all areas of life, including the rock art domain—much as in coeval Europe but, in the South African case, in a paleontological context that, if non-Neandertal, is not modern human either and is perhaps succinctly best referred to as near-modern (Trinkaus 2005).

Future research will show whether these speculations are supported. For the time being, they serve to illustrate the "Brave New World" that opens to Paleoanthropology if it dares to remove the Human Revolution eye-band that, as also argued by McBrearty and Brooks (2000) for the African record for so long blinded scholars to the evidence concerning the behavioral "modernity" of anatomically "archaic" humans. Hopefully, what the last 15 years of developments in the study of the emergence of the Upper Paleolithic and modern humans will have taught us is that the transformations we see in the archeological and human paleontological records of that time have deep roots in the preceding Middle Paleolithic and its non-"modern" populations.

Rather than discussing the reality of the chronology of the Middle-to-Upper Paleolithic and Neandertal to modern human transitions in Europe apparent when respecting the "primacy of stratigraphy" principle (Zilhão et al. 2011), future research should concentrate, at an empirical level, on refining it to the extent possible with current techniques; as the preceding sections illustrate, developing a better understanding of the applicability (and limits) of Bayesian methods to the interpretation of dating results in a stratigraphic context is also badly needed. At a theoretical level, the chronology of those transitions also carries implications for the understanding of how, between 100,000 and 40,000 years ago, convergent developments led toward symbolic material cultures in both Africa and Eurasia; in a scenario where the very phenomenon of anatomical Neandertalness implies a significant level of isolation between these continents (Wolpoff 2009), what kinds of processes explain what nonetheless happened? Where the changes in social structure reflected in the emergence of symbolic material culture are concerned, a complex interplay of numerous factors—natural selection, technological progress, demographic pressure, climate change, response to catastrophic events, etc.,—clearly must be involved. Explanations will therefore have to be based on historical models that try to capture this complexity instead of reducing it to some *deus ex machina*, whatever its nature (genetical, cognitive, adaptive, etc.).

3.7 Conclusion

Elsewhere (Zilhão 2012), I have argued that a persistent, if subconscious influence in academia of Victorian-age ideas of evolution-as-progress and ancient-as-primitive must go a long way into explaining ongoing Neandertal debates. I certainly have no better explanation for the continued attempts at negating the clear and unambiguous, if limited (by comparison with later periods) evidence for Middle Paleolithic and pre-modern human symbolism accumulated over the last 15 years. In other scientific domains, the distortions of method and logic involved in such attempts would hardly go unnoticed, but they remain all-pervasive in Neandertal and modern human origins controversies.

The unwarranted application of Bayesian statistics in the modeling of radiocarbon results for this period is a good example of this problem. As applied by, for instance, Higham et al. (2010, 2011c, d, 2012), that is, coupled with outlier analysis, the approach needs to deal with the following logical issues: (a) if stratigraphic ordering is assumed, the outlier analysis will detect analytical error in the dating; (b) if dating accuracy is assumed, the outlier analysis will detect stratigraphic disorder; (c) if neither stratigraphic ordering nor dating accuracy can be assumed, then the Bayesian approach cannot be applied.

Given this, where Bayesian modeling is potentially of most use is in dealing with issues of chronostratigraphy, as in Banks et al.'s (2013) study of the timing and causes of the change from Protoaurignacian to Aurignacian I in Western Europe. This is because, under the axiomatic principles of Paleolithic archeology, the repetitive pattern of stratigraphic succession whereby the Protoaurignacian always precedes the Aurignacian I carries two important implications: firstly, that any time lags that may have existed in the succession of one by the other across the continuous geographic space where both occur are undetectable and of negligible consequence for the kinds of questions that archaeology can address; secondly, that any overlap in dating results can therefore be treated as reflecting no more than the statistical uncertainty inherent to the dating technique. In this context, case (a) of the preceding paragraph can be safely assumed and any anomalies detected can be treated just as exactly that—anomalies ("outliers").

When dealing with successions that are specific to a single site, however, whether case (a), (b) or (c) applies depends on a different type of external referent, and that referent can only be that site's taphonomic study. If refitting work or the vertical distributions of diagnostic finds yield results that are coherent with the stratigraphic outline underpinning the ascription of samples to Bayesian "phases," then the approach is viable but the implication is that outliers primarily reflect dating error, not stratigraphic disturbance. If the same types of evidence show that the stratigraphic sequence is unreliable, or that the boundaries between stratigraphic units are fuzzy, then the Bayesian approach is not viable; this is either because the samples' time ordering indicated by stratigraphic provenience is apparent, not real, or because the discretization of the sequence into Bayesian "phases" is unwarranted and the sequence has to be treated as a single continuum where the interpretation of individual results is contingent upon contextual, not mathematical arguments. Regrettably, most recent implementations of Bayesian methods to sets of dates related to the Middle-to-Upper Paleolithic transition in Europe have ignored these logical issues.

The widespread application of double standards in the assessment of the evidence is another aspect of the same problem. Take the set of conditions put forward by Higham et al. (2011b) to change their minds on the issue of stratigraphic integrity vs. sample contamination raised by Zilhão et al. (2011) in relation to the results obtained by the ORAU for the Grotte du Renne. Higham et al. contend that it falls upon their critics "to prove conclusively that the [excavator's] stratigraphic interpretation was without fault … [and] that *all* of the material is in situ" [my emphasis]. This stand reverses the burden of proof: if inferences about the past cannot be made from a site where, despite minor problems, the vertical and horizontal distribution of the diagnostic finds has the extraordinary coherence that Caron et al. (2011) documented and Higham et al. did not question, then archeology would be an impossible discipline. Moreover, accepting the behavioral implications of those distributions in no way requires meeting Higham et al.'s conditions. Neandertal symbolism can be inferred from the Grotte du Renne even if only some of the material is in situ, because, obviously, Neandertals would not cease to be symbolic simply because the number of in situ ornaments in level X turned out to be, instead of 29, say, 19 (or 9, or only 4), nor would they become super-symbolic if that number were of, say, 59 (or 590, or 5,900). This is an issue of quality, not quantity.

Interestingly, it is indisputable that the kind of proof requested by Higham et al. has not been provided for any of the sites reviewed here and invoked in support of the notion of a precocious settlement of Europe by modern humans—Kent's Cavern, Cavallo, Kebara, Geissenklösterle, etc. In fact, no one has even so much as pretended that these sites meet the over-stringent criteria requested from the Grotte du Renne, and the publication of the dating evidence contains explicit remarks concerning observed or potential post-depositional disturbance. Yet, when dealing with those other sites, the dating experts felt their case was strong enough for inferences of major paleoanthropological significance to be made, and these are by and large the same authors who, for the Grotte du Renne, require that the stratigraphy be proven without fault.

It should go without saying that "conclusive proof that all the material is in situ" is something that has never been provided for any archeological site whatsoever. In fact, as in proving that God does not exist and similar philosophical problems, such a demonstration simply cannot be made—and, indeed, requesting a set of impossible conditions as a precondition to retract is a stance that one seldom finds, if at all, in scientific debates … except, that is, when it comes to Neandertals and modern humans. One can only hope the day will come when that shall be the case no more.

Acknowledgments I thank the organizers of the Tokyo conference on the "Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning" (November 18–24, 2012) for their invitation to participate in such an instructive event. I am especially grateful to Ofer Bar-Yosef for his assistance in obtaining the material from the Kebara archive reproduced here. Paul Bahn, William Banks, Ofer Bar-Yosef, Francesco d'Errico, Alistair Pike, Nicolas Teyssandier, Erik Trinkaus and an anonymous reviewer read preliminary versions of the manuscript and offered valuable comments and/or critique. As usual, any errors or omissions are my own.

References

Bailey SE, Hublin JJ (2006) Dental remains from the Grotte du Renne at Arcy-sur-Cure (Yonne). J Hum Evol 50:485–508

Bailey SE, Weaver TD, Hublin JJ (2009) Who made the Aurignacian and other early Upper Paleolithic industries? J Hum Evol 57:11–26

Banks WE, d'Errico F, Zilhão J (2013) Human-climate interaction during the early Upper Paleolithic: testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian. J Hum Evol 64:39–55

Bar-Yosef O (2006) Neanderthals and Modern Humans: a different interpretation. In: Conard NJ (ed) When Neanderthals and Modern humans met. Kerns, Tübingen, pp 467–482

Bar-Yosef O, Bordes JG (2010) Who were the makers of the Châtelperronian culture? J Hum Evol 59:586–593

Bar-Yosef O, Meignen L (eds) (2007) Kebara Cave, Mt Carmel, Israel: the Middle and Upper Paleolithic Archaeology, part I. American School of Prehistoric Research/Peabody Museum of Archaeology and Ethnology, Cambridge

Bar-Yosef O, Arnold M, Mercier N, Belfer-Cohen A, Goldberg P, Housley R, Laville H, Meignen L, Vogel JC, Vandermeersch B (1996) The dating of the Upper Paleolithic Layers in Kebara Cave, Mt Carmel. J Archaeol Sci 23:297–306

Bayle P, Macchiarelli R, Trinkaus E, Duarte C, Mazurier A, Zilhão J (2010) Dental maturational sequence and dental tissue proportions in the early Upper Paleolithic child from Abrigo do Lagar Velho, Portugal. Proc Natl Acad Sci U S A 107:1338–1342

Belfer-Cohen A, Goring-Morris AN (2003) Current issues in Levantine Upper Palaeolithic research. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye: Studies on Upper Palaeolithic diversity in the Near East. Oxbow, Oxford, pp 1–12

Benazzi S, Douka K, Fornai C, Bauer CC, Kullmer O, Svoboda J, Pap I, Mallegni F, Bayle P, Coquerelle M, Condemi S, Ronchitelli A, Harvati K, Weber GW (2011) Early dispersal of modern humans in Europe and implications for Neanderthal behaviour. Nature 479:525–529

Benazzi S, Fornai C, Buti L, Toussaint M, Mallegni F, Ricci S, Gruppioni G, Weber GW, Condemi S, Ronchitelli A (2012) Cervical and crown outline analysis of worn Neanderthal and modern human lower second deciduous molars. Am J Phys Anthropol 149:537–546

Bergman CA, Stringer CB (1989) Fifty years after: Egbert, an early Upper Palaeolithic juvenile from Ksar Akil, Lebanon. Paléorient 15:99–111

Binford L (1983) In Pursuit of the Past. Thames and Hudson, London

Bodu P (1990) L'application de la méthode des remontages à l'étude du matériel lithique des premiers niveaux châtelerroniens d'Arcy-sur-Cure. In: Farizy C (ed) Paléolithique moyen récent et Paléolithique supérieur ancien en Europe. Musée de Préhistoire de l'Ile de France, Nemours, pp 309–312

Bon F (2002) L'Aurignacien entre Mer et Océan. Réflexion sur l'unité des phases anciennes de l'Aurignacien dans le sud de la France. Société Préhistorique Française, Paris

Bon F, Bodu P (2002) Analyse technologique du débitage aurignacien. In: Schmider B (ed) L'Aurignacien de la grotte du Renne. Les fouilles d'André Leroi-Gourhan à Arcy-sur-Cure (Yonne). CNRS, Paris, pp 115–133

Bordes F (1980) Question de contemporanéité : l'illusion des remontages. Bull Soc Préhist Franç 77:132–133

Bordes JG, Teyssandier N (2011) The Upper Paleolithic nature of the Châtelperronian in South-Western France: Archeostratigraphic and lithic evidence. Quat Int 246:382–388

Bouzouggar A, Barton N (2012) The identity and timing of the Aterian in Morocco. In: Hublin JJ, McPherron SP (eds) Modern origins: a North African perspective. Springer, New York, pp 93–105

Bouzouggar A, Barton N, Vanhaeren M, d'Errico F, Collcutt S, Higham T, Hodge E, Parfitt S, Rhodes E, Schwenninger JL, Stringer C, Turner E, Ward S, Moutmir A, Stambouli A (2007) 82,000-Year-old shell beads from North Africa and implications for the origins of modern human behavior. Proc Natl Acad Sci U S A 104:9964–9969

Brock F, Higham T (2009) AMS radiocarbon dating of Paleolithic-aged charcoal from Europe and the Mediterranean rim using ABOX-SC. Radiocarbon 51:839–846

Bronk Ramsey C (2009) Bayesian analysis of radiocarbon dates. Radiocarbon 51:337–360

Camps M, Higham T (2012) Chronology of the Middle to Upper Palaeolithic transition at Abric Romaní, Catalunya. J Hum Evol 62:89–103

Caron F, d'Errico F, Del Moral P, Santos F, Zilhão J (2011) The reality of Neandertal symbolic behavior at the Grotte du Renne, Arcy-sur-Cure. PLoS One 6:e21545

Chiotti L (1999) Les industries lithiques des niveaux aurignaciens de l'Abri Pataud, Les Eyzies-de-Tayac (Dordogne): étude technologique et typologique. Ph.D. dissertation, Institut de Paléontologie Humaine

Churchill SE, Smith FH (2000) Makers of the Early Aurignacian of Europe. Yearbook Phys Anthropol 43:61–115

Conard NJ (2008) A critical view of the evidence for a southern African origin of behavioural modernity. South African Archaeol Soc Goodwin Ser 10:175–179

Conard NJ, Bolus M (2003) Radiocarbon dating the appearance of modern humans and timing of cultural innovations in Europe: new results and new challenges. J Hum Evol 44:331–371

Conard NJ, Grootes PM, Smith FH (2004) Unexpectedly recent dates for human remains from Vogelherd. Nature 430:198–201

Conard NJ, Bolus M, Goldberg P, Munzel SC (2006) The last Neanderthals and first modern humans in the Swabian Jura. In: Conard NJ (ed) When Neanderthals and Modern Humans met. Kerns, Tübingen, pp 305–341

d'Errico F (2003) The invisible frontier. A multiple species model for the origin of behavioral modernity. Evol Anthropol 12:188–202

d'Errico F, Zilhão J, Baffier D, Julien M, Pelegrin J (1998) Neanderthal acculturation in western Europe? A critical review of the evidence and its interpretation. Curr Anthropol 39:S1S44

d'Errico F, Borgia V, Ronchitelli A (2012) Uluzzian bone technology and its implications for the origin of behavioural modernity. Quat Int 259:59–71

David F, Connet N, Girard M, Lhomme V, Miskovsky JC, Roblin-Jouve A (2001) Le Châtelperronien de la grotte du Renne à Arcy-sur-Cure (Yonne). Données sédimentologiques et chronostratigraphiques. Bull Soc Préhist Franç 98:207–230

De Vivo B, Rolandi G, Gans B, Calvert A, Bohrson WA, Spera FJ, Belkin HE (2001) New constraints on the pyroclastic eruptive history of the Campanian volcanic Plain (Italy). Mineral Petrol 73:47–65

Douka K (2011) An Upper Palaeolithic shell scraper from Ksar Akil (Lebanon). J Archaeol Sci 38:429–437

Douka K, Grimaldi S, Boschian G, Del Lucchese A, Higham TFG (2012) A new chronostratigraphic framework for the Upper Palaeolithic of Riparo Mochi (Italy). J Hum Evol 62:286–299

Duarte C, Maurício J, Pettitt PB, Souto P, Trinkaus E, van der Plicht H, Zilhão J (1999) The early Upper Paleolithic human skeleton from the Abrigo do Lagar Velho (Portugal) and modern human emergence in Iberia. Proc Natl Acad Sci U S A 96:7604–7609

Finlayson C, Brown K, Blasco R, Rosell J, Negro JJ, Bortolotti GR, Finlayson G, Sánchez Marco A, Giles Pacheco F, Rodríguez Vidal J, Carrión JS, Fa DA, Rodríguez Llanes JM (2012) Birds of a feather: Neanderthal exploitation of raptors and corvids. PLoS One 7:e45927

Flas D (2011) The Middle to Upper Paleolithic transition in Northern Europe: the Lincombian–Ranisian–Jerzmanowician and the issue of acculturation of the last Neanderthals. World Archaeol 43:605–627

Gambassini P, Mallegni F, Ricci S (2005) Reperti Dentari dagli Strati Uluzziani di Grotta del Cavallo (Lecce): Stato dell'Arte su Stratigrafia e Aspetti Biologici. In: Guerci A, Consigliere S, Castagno S (eds) Atti del XVI Congresso degli Antropologi Italiani. Il processo di umanizzazione. Genova

Green RE, Krause J, Briggs AW, Maricic T, Stenzel U, Kircher M, Patterson N, Li H, Zhai W, Fritz MHY, Hansen NF, Durand EY, Malaspinas AS, Jensen J, Marques-Bonet T, Alkan C, Prüfer K, Meyer M, Burbano HA, Good JM, Schultz R, Aximu-Petri A, Butthof A, Höber B, Höffner B, Siegemund M, Weihmann A, Nusbaum C, Lander ES, Russ C, Novod N, Affourtit J, Egholm M, Verna C, Rudan P, Brajkovic D, Kucan Ž, Gušic I, Doronichev VB, Golovanova LV, Lalueza-Fox C, de la Rasilla M, Fortea J, Rosas A, Schmitz RW, Johnson LF, Eichler EE, Falush D, Birney E, Mullikin JC, Slatkin M, Nielsen R, Kelso J, Lachmann M, Reich D, Pääbo S (2010) A draft sequence of the Neandertal genome. Science 328:710–722

Gioia P (1990) An aspect of the transition between Middle and Upper Palaeolithic in Italy: the Uluzzian. In: Farizy C (ed) Paléolithique moyen récent et Paléolithique supérieur ancien en Europe. Musée de Préhistoire de l'Ile de France, Nemours, pp 241–250

Goldberg P, Laville H, Meignen L, Bar-Yosef O (2007) Stratigraphy and geoarchaeological history of Kebara Cave, Mount Carmel. In: Bar-Yosef O, Meignen L (eds) Kebara cave, Mt Carmel, Israel: the Middle and Upper Paleolithic Archaeology, part I. American School of Prehistoric Research/Peabody Museum of Archaeology and Ethnology, Cambridge, pp 49–89

Gravina B, Mellars P, Bronk Ramsey C (2005) Radiocarbon dating of interstratified Neanderthal and early modern human occupations at the Chatelperronian type-site. Nature 438:51–56

Hahn J (1977) Aurignacien, das ältere Jungpaläolithikum in Mittel- und Osteuropa. Böhlau, Köln/Wien

Hahn J (1988) Das Geissenklösterle I. Konrad Theiss, Stuttgart

Hawks J (2012) Dynamics of genetic and morphological variability within Neandertals. J Archaeol Sci 90:1–17

Higham T (2011) European Middle and Upper Palaeolithic radiocarbon dates are often older than they look: problems with previous dates and some remedies. Antiquity 85:235–249

Higham TFG, Brock F, Peresani M, Broglio A, Wood R, Douka K (2009) Problems with radiocarbon dating the Middle to Upper Palaeolithic transition in Italy. Quat Sci Rev 28:1257–1267

Higham TFG, Jacobi RM, Julien M, David F, Basell L, Wood R, Davies W, Bronk Ramsey C (2010) Chronology of the Grotte du Renne (France) and implications for the context of ornaments and human remains within the Châtelperronian. Proc Natl Acad Sci U S A 107:20234–20239

Higham TFG, Brock F, Bronk Ramsey C, Davies W, Wood R, Basell L (2011a) Chronology of the site of Grotte du Renne, Arcy-sur-Cure, France: implications for Neanderthal symbolic behaviour. Before Farm 2011(2):1–9, article 1

Higham TFG, Brock F, Bronk Ramsey C, Davies W, Wood R, Basell L (2011b) Chronology of the Grotte du Renne, Arcy-sur-Cure, France: a response to Zilhão et al (this issue). Before Farm 2011(3):1–5, article 4

Higham T, Compton T, Stringer C, Jacobi R, Shapiro B, Trinkaus E, Chandler B, Gröning F, Collins C, Hillson S, O'Higgins P, Fitzgerald C, Fagan M (2011c) The earliest evidence for anatomically modern humans in northwestern Europe. Nature 479:521–524

Higham T, Jacobi R, Basell L, Bronk Ramsey C, Chiotti L, Nespoulet R (2011d) Precision dating of the Palaeolithic: a new radiocarbon chronology for the Abri Pataud (France), a key Aurignacian sequence. J Hum Evol 61:549–563

Higham T, Basell L, Jacobi RM, Wood R, Bronk Ramsey C, Conard NJ (2012) Testing models for the beginnings of the Aurignacian and the advent of figurative art and music: the radiocarbon chronology of Geißenklösterle. J Hum Evol 62:664–676

Hoffmann D, Pike AWG, Wainer K, Zilhão J (2013) New U-series results for the speleogenesis and the Palaeolithic archaeology of the Almonda karstic system (Torres Novas, Portugal). Quat Int 294:168–182

Holliday TW (2006) Neanderthals and modern humans: an example of a mammalian syngameon? In: Harvati K, Harrison T (eds) Neanderthals revisited: new approaches and perspectives. Springer, New York, pp 289–306

Hublin JJ (2000) Modern-nonmodern hominid interactions: a Mediterranean perspective. In: Bar-Yosef O, Pilbeam D (eds) The geography of Neandertals and modern humans in Europe and the Greater Mediterranean. Peabody Museum, Cambridge, pp 157–182

Hublin JJ, Spoor F, Braun M, Zonneveld F, Condemi S (1996) A late Neanderthal associated with Upper Palaeolithic artefacts. Nature 381:224–226

Hublin JJ, Talamo S, Julien M, David F, Connet N, Bodu P, Vandermeersch B, Richards MP (2012a) Radiocarbon dates from the Grotte du Renne and Saint-Césaire support a Neandertal origin for the Châtelperronian. Proc Natl Acad Sci U S A 109:18743–18748

Hublin JJ, Verna C, Bailey SE, Smith T, Olejniczak A, Sbihi-Alaoui FZ, Zouak M (2012b) Dental evidence from the Aterian human populations of Morocco. In: Hublin JJ, McPherron SP (eds) Modern origins: a North African perspective vertebrate. Springer, New York, pp 189–204

Jacobi RM, Higham TFG (2011) The British earlier Upper Palaeolithic: settlement and chronology. In: Ashton N, Lewis S, Stringer C (eds) The ancient human occupation of Britain. Elsevier, Amsterdam, pp 181–222

Jones M, Marks AE, Kaufman D (1983) Boker. The artifacts. In: Marks AE (ed) Prehistory and paleoenvironments in the central Negev, Israel. The Avdat/Aqev Area, Part 3, vol III. Southern Methodist University, Dallas, pp 283–329

Julien M, Baffier D, Liolios D (2002) L'industrie osseuse. In: Schmider B (ed) L'Aurignacien de la grotte du Renne. Les fouilles d'André Leroi-Gourhan à Arcy-sur-Cure (Yonne). CNRS, Paris, pp 217–250

Klein RG (1992) The archaeology of modern human origins. Evol Anthropol 1:5–14

Koumouzelis M, Ginter B, Kozłowski JK, Pawlikowski M, Bar-Yosef O, Albert RM, Litynska-Zajac M, Stworzewicz E, Wojtal P, Lipecki G, Tomek T, Bochenski ZM, Pazdur A (2001a) The Early Upper Palaeolithic in Greece: the excavations in Klisoura cave. J Archaeol Sci 28:515–539

Koumouzelis M, Kozłowski JK, Escutenaire C, Sitlivy V, Sobczyk K, Valladas H, Tisnerat-Laborde N, Wojtal P, Ginter B (2001b) La fin du Paléolithique moyen et le début du Paléolithique supérieur en Grèce : la séquence de la Grotte 1 de Klissoura. L'anthropol 105:469–504

Kuhn SL (2002) Paleolithic archeology in Turkey. Evol Anthropol 11:198–210

Kuhn SL (2003) In what sense is the Levantine Initial Upper Paleolithic a "transitional" industry? In: Zilhão J, d'Errico F (eds) The chronology of the Aurignacian and of the transitional technocomplexes. Dating, stratigraphies, cultural implications. Instituto Português de Arqueologia, Lisboa, pp 61–69

Kuhn SL, Stiner MC, Reese DS, Güleç E (2001) Ornaments of the earliest Upper Paleolithic: new insights from the Levant. Proc Natl Acad Sci U S A 98(13):7641–7646

Kuhn SL, Stiner MC, Güleç E, Özer I, Yilmaz H, Baykara I, Açikkol A, Goldberg P, Martínez Molina K, Ünay E, Suata-Alpaslan F (2009) The early Upper Paleolithic occupations at Üçağızlı Cave (Hatay, Turkey). J Hum Evol 56:87–113

Le Cabec A, Gunz P, Kupczik K, Braga J, Hublin JJ (2013) Anterior tooth root morphology and size in Neanderthals: taxonomic and functional implications. J Hum Evol 64:169–193

Leroi-Gourhan A (1958) Etude des restes humains fossiles provenant des Grottes d'Arcy-sur-Cure. Annal Paléontol 44:87–148

Lévêque F, Vandermeersch B (1980) Découverte de restes humains dans un niveau castelperronien à Saint-Césaire (Charente-Maritime). Comptes Rendus de l'Académie des Sciences de Paris 291D:187–189

Marks AE (1983) The sites of Boker and Boker Tachtit: a brief introduction In: Marks AE (ed) Prehistory and paleoenvironments in the central Negev, Israel. Vol. III. The Avdat/Aqev Area, Part 3. Southern Methodist University, Dallas, pp 15–37

McBrearty S, Brooks A (2000) The revolution that wasn't: a new interpretation of the origin of modern human behavior. J Hum Evol 39:453–563

Mellars PA (1999) The Neanderthal problem continued. Curr Anthropol 40(3):341350

Mellars PA (2004) Neanderthals and the modern human colonization of Europe. Nature 432:461–465

Mellars PA (2010) Neanderthal symbolism and ornament manufacture: the bursting of a bubble? Proc Natl Acad Sci U S A 107:20147–20148

Mellars PA, Gravina B (2008) Châtelperron: theoretical agendas, archaeological facts, and diversionary smoke-screens. PaleoAnthropol 2008:43–64

Mellars PA, Stringer CB (eds) (1989) The Human Revolution. University Press, Edinburgh

Mellars PA, Gravina B, Bronk Ramsey C (2007) Confirmation of Neanderthal/modern human interstratification at the Chatelperronian type-site. Proc Natl Acad Sci U S A 104:3657–3662

Monigal K (2003) Technology, economy and mobility at the beginning of the Levantine Upper Palaeolithic. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye. Studies on Upper Palaeolithic diversity in the Near East. Oxbow, Oxford, pp 118–133

Moreau L (2009) Geißenklösterle. Das Gravettien der Schwäbischen Alb im europäischen Kontext. Kerns Verlag, Tübingen

Moreau L (2010) Geisenklösterle. The Swabian Gravettian in its European context. Quartär 57:79–93

Moreau L (2012) Le Gravettien ancien d'Europe centrale revisité: mise au point et perspectives. L'anthropol 116:609–638

Morin E, Laroulandie V (2012) Presumed symbolic use of diurnal raptors by Neanderthals. PLoS One 7:e32856

Morin E, Tsanova T, Sirakov N, Rendu W, Mallye JB, Lévêque F (2005) Bone refits in stratified deposits: testing the chronological grain at Saint-Césaire. J Archaeol Sci 32:1083–1098

Moroni A, Boscato P, Ronchitelli A (2012) What roots for the Uluzzian? Modern behaviour in Central-Southern Italy and hypotheses on AMH dispersal routes. Quat Int. doi:10.1016/j.quaint.2012.10.051

Münzel SC, Conard NJ (2004) Change and continuity in subsistence during the Middle and Upper Palaeolithic in the Ach Valley of Swabia (South-west Germany). Intl J Osteoarchaeol 14:225–243

Nigst R, Haesaerts P (2012) L'Aurignacien en Basse Autriche : résultats préliminaires de l'analyse technologique de la couche culturelle 3 de Willendorf II et ses implications pour la chronologie du Paléolithique supérieur ancien en Europe centrale. L'anthropol 116:575–608

Nigst R, Bence Viola TH, Haesaerts P, Blockley S, Damblon F, Frank C, Fuchs M, Götzinger M, Hambach U, Mallol C, Moreau L, Niven L, Richards M, Richter D, Zöller L, Trnka G, Hublin JJ (2008) New research on the Aurignacian of Central Europe: a first note on the 2006 fieldwork at Willendorf II. Quartär 55:9–15

Peresani M, Fiore I, Gala M, Romandini M, Tagliacozzo A (2011) Late Neandertals and the intentional removal of feathers as evidenced from bird bone taphonomy at Fumane Cave 44 ky B.P., Italy. Proc Natl Acad Sci U S A 108:3888–3893

Pesesse D (2008) Les premières sociétés gravettiennes. Analyse comparée des systèmes lithiques de la fin de l'Aurignacien aux débuts du Gravettien. Ph.D. dissertation, University of Provence

Pesesse D (2010) Quelques repères pour mieux comprendre l'émergence du Gravettien en France. Bull Soc Préhist Franç 107:465–487

Pike AWG, Hoffmann DL, García-Diez M, Pettitt PB, Alcolea J, de Balbin R, González-Sainz C, de las HC, Lasheras JA, Montes R, Zilhão J (2012) U-series dating of Paleolithic art in 11 caves in Spain. Science 336:1409–1413

Pinhasi R, Higham TFG, Golovanova LV, Doronichev VB (2011) Revised age of late Neanderthal occupation and the end of the Middle Paleolithic in the northern Caucasus. Proc Natl Acad Sci U S A 108:8611–8616

Rebollo NR, Weiner S, Brock F, Meignen L, Goldberg P, Belfer-Cohen A, Bar-Yosef O, Boaretto E (2011) New radiocarbon dating of the transition from the Middle to the Upper Paleolithic in Kebara Cave, Israel. J Archaeol Sci 38:2424–2433

Reimer PJ, Baillie MGL, Bard E, Bayliss A, Beck JW, Bertrand C, Blackwell PG, Buck CE, Burr G, Cutler KB, Damon PE, Edwards RL, Fairbanks RG, Friedrich M, Guilderson TP, Hughen KA, Kromer B, McCormac FG, Manning S, Bronk Ramsey C, Reimer RW, Remmele S, Southon JR, Stuiver M, Talamo S, Taylor FW, van der Plicht J, Weyhenmeyer CE (2009) Intcal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years Cal BP. Radiocarbon 51:1111–1150

Riel-Salvatore J (2009) What is a 'transitional' industry? The Uluzzian of southern Italy as a case study. In: Camps M, Chauhan PR (eds) A sourcebook of Paleolithic transitions. Springer, New York, pp 377–396

Semal P, Rougier H, Crevecoeur I, Jungels C, Flas D, Hauzeur A, Maureille B, Germonpré M, Bocherens H, Pirson S, Cammaert L, de Clerck N, Hambucken A, Higham T, Toussaint M, van der Plicht J (2009) New data on the late Neandertals: direct dating of the Belgian Spy fossils. Am J Phys Anthropol 138:421–428

Soressi M (2011) Révision taphonomique et techno-typologique des deux ensembles attribués au Châtelperronien de la Roche-à-Pierrot à Saint-Césaire. L'anthropol 115:569–584

Soressi M, d'Errico F (2007) Pigments, gravures, parures: les comportements symboliques controversés des Néandertaliens. In: Vandermeersch B, Maureille B (eds) Les Néandertaliens. Biologie et cultures. Éditions du CTHS, Paris, pp 297–309

Stuiver M, Reimer PJ (1993) Extended ^{14}C data base and revised CALIB 3.0 ^{14}C Age calibration program. Radiocarbon 35:215230

Taborin Y (1998) Comment to d'Errico F, Zilhão J, Julien M, Baffier D, Pelegrin J, Neandertal acculturation in western Europe? A critical review of the evidence and its interpretation. Curr Anthropol 39:28–29

Taborin Y (2002) Les objets de parure et les curiosa. In: Schmider B (ed) L'Aurignacien de la grotte du Renne: les fouilles d'André Leroi-Gourhan à Arcy-sur-Cure (Yonne). CNRS, Paris, pp 251–256

Talamo S, Soressi M, Roussel M, Richards M, Hublin JJ (2012) A radiocarbon chronology for the complete Middle to Upper Palaeolithic transitional sequence of Les Cottés (France). J Archaeol Sci 39:175–183

Texier PJ, Porraz G, Parkington J, Rigaud JP, Poggenpoel C, Miller C, Tribolo C, Cartwright C, Coudenneau A, Klein R, Steele T, Verna C (2010) A Howiesons Poort tradition of engraving ostrich eggshell containers dated to 60,000 years ago at Diepkloof Rock Shelter, South Africa. Proc Natl Acad Sci U S A 107:6180–6185

Teyssandier N (2003) Les débuts de l'Aurignacien en Europe. Discussion à partir des sites de Geissenklösterle, Willendorf II, Krems-Hundssteig et Bacho Kiro. Ph. D. dissertation, University of Paris X

Teyssandier N (2008) Revolution or evolution: the emergence of the Upper Paleolithic in Europe. World Archaeol 40:493–519

Teyssandier N, Liolios D (2003) Defining the earliest Aurignacian in the Swabian Alb: the relevance of the Geißenklösterle (Baden-Württemberg, Germany) lithic and organic productions. In: Zilhão J, d'Errico F (eds) The chronology of the Aurignacian and of the transitional technocomplexes. Dating, stratigraphies, cultural implications. Instituto Português de Arqueologia, Lisboa, pp 179–196

Trinkaus E (2005) Early modern humans. Annu Rev Anthropol 34:207–230

Trinkaus E (2007) European early modern humans and the fate of the Neandertals. Proc Natl Acad Sci U S A 104:7367–7372

Trinkaus E, Zilhão J (2013) Paleoanthropological implications of the Peştera cu Oase and its contents. In: Trinkaus E, Constantin S, Zilhão J (eds) Life and death at the Peştera cu Oase: a setting for modern human emergence in Europe. Oxford University Press, New York, pp 389–400

Trinkaus E, Churchill SE, Ruff CB, Vandermeersch B (1999) Long bone shaft robusticity and body proportions of the Saint-Césaire 1 Châtelperronian Neanderthal. J Archaeol Sci 26:753–773

Trinkaus E, Constantin S, Zilhão J (eds) (2013) Life and death at the Peştera cu Oase: a setting for modern human emergence in Europe. Oxford University Press, New York

Valladas H, Joron JL, Valladas G, Arensburg B, Bar-Yosef O, Belfer-Cohen A, Goldberg P, Laville H, Meignen L, Rak Y, Tchernov E, Tillier AM, Vandermeersch B (1987) Thermoluminescence dates for the Neanderthal burial site at Kebara in Israel. Nature 330:159–160

Vallois H (1949) The Fontéchevade fossil man. Am J Phys Anthropol 7:339–362

Vandermeersch B (1993) Was the Saint-Césaire discovery a burial? In: Lévêque F, Backer AM, Guilbaud M (eds) Context of a Late Neandertal. Prehistory, Madison, pp 129–131

Vaquero M, Carbonell E (2012) Some clarifications on the Middle-Upper Paleolithic transition in Abric Romaní: Reply to Camps and Higham (2012). J Hum Evol 63:711–717

Ward GK, Wilson SR (1978) Procedures for comparing and combining radiocarbon age determinations: a critique. Archaeometry 20:19–31

White M, Pettitt P (2012) Ancient digs and modern myths: the age and context of the Kent's Cavern 4 maxilla and the earliest *Homo sapiens* specimens in Europe. Eur J Archaeol 15:1–30

White R (2001) Personal ornaments from the Grotte du Renne at Arcy-sur-Cure. Athena Rev 2:41–46

White R (2002) Observations technologiques sur les objets de parure. In: Schmider B (ed) Les fouilles d'André Leroi-Gourhan à Arcy-sur-Cure (Yonne). CNRS, Paris, pp 257–266

White R, Mensan R, Bourrillon R, Cretin C, Higham TFG, Clarke AE, Sisk ML, Tartar E, Gardère P, Goldberg P, Pelegrin J, Valladas H, Tisnérat-Laborde N, de Sanoit J, Chambellan D, Chiotti L (2012) Context and dating of Aurignacian vulvar representations from Abri Castanet, France. Proc Natl Acad Sci U S A 109:8450–8455

Wood R, Barroso-Ruíz C, Caparrós M, Jordá Pardo JF, Galván Santos B, Higham TFG (2013) Radiocarbon dating casts doubt on the late chronology of the Middle to Upper Palaeolithic transition in southern Iberia. Proc Natl Acad Sci U S A 110:2781–2786

Wolpoff M (2002) Human paleontology. University of Michigan, Ann Arbor

Wolpoff M (2009) How Neandertals inform human variation. Am J Phys Anthropol 139:91–102

Wolpoff M, Smith FH, Malez M, Radovčić J, Rukavina D (1981) Upper Pleistocene human remains from Vindija Cave, Croatia, Yugoslavia. Am J Phys Anthropol 54:499–545

Zilhão J (2006a) Neandertals and moderns mixed, and it matters. Evol Anthropol 15:183–195

Zilhão J (2006b) Aurignacian, behavior, modern: Issues of definition in the emergence of the European Upper Paleolithic. In: Bar-Yosef O, Zilhão J (eds) Towards a definition of the Aurignacian. American School of Prehistoric Research/Instituto Português de Arqueologia, Lisboa, pp 53–69

Zilhão J (2007) The emergence of ornaments and art: an archaeological perspective on the origins of behavioural "modernity". J Archaeol Res 15:1–54

Zilhão J (2011) Aliens from outer time? Why the "Human Revolution" is wrong, and where do we go from here? In: Condemi S, Weniger G-C (eds) Continuity and discontinuity in the peopling of Europe: one hundred fifty years of Neanderthal Study. Springer, New York, pp 331–366

Zilhão J (2012) Personal ornaments and symbolism among the Neanderthals. In: Elias S (ed) Origins of human innovation and creativity. Elsevier, London, pp 35–49

Zilhão J, d'Errico F (1999) The chronology and taphonomy of the earliest Aurignacian and its implications for the understanding of Neanderthal extinction. J World Prehist 13:1–68

Zilhão J, d'Errico F (2003) An Aurignacian "Garden of Eden" in southern Germany? An alternative interpretation of the Geissenklösterle and a critique of the Kulturpumpe model. Paléo 15:69–86

Zilhão J, Angelucci D, Badal-García E, d'Errico F, Daniel F, Dayet L, Douka K, Higham TFG, Martínez-Sánchez MJ, Montes-Bernárdez R, Murcia-Mascarós S, Pérez-Sirvent C, Roldán-García C, Vanhaeren M, Villaverde V, Wood R, Zapata J (2010a) Symbolic use of marine shells and mineral pigments by Iberian Neandertals. Proc Natl Acad Sci U S A 107:1023–1028

Zilhão J, Davis SJM, Duarte C, Soares AMM, Steier P, Wild E (2010b) Pego do Diabo (Loures, Portugal): Dating the emergence of anatomical modernity in westernmost Eurasia. PLoS One 5:e8880

Zilhão J, d'Errico F, Bordes JG, Lenoble A, Texier JP, Rigaud JP (2006) Analysis of Aurignacian interstratification at the Châtelperronian-type site and implications for the behavioral modernity of Neandertals. Proc Natl Acad Sci U S A 103:12643–12648

Zilhão J, d'Errico F, Bordes JG, Lenoble A, Texier JP, Rigaud JP (2008a) Grotte des Fées (Châtelperron): History of research, stratigraphy, dating, and archaeology of the Châtelperronian type-site. Paleoanthropol 2008:1–42

Zilhão J, d'Errico F, Bordes JG, Lenoble A, Texier JP, Rigaud JP (2008b) Like Hobbes' chimney birds. Paleoanthropology 2008:65–67

Zilhão J, d'Errico F, Julien M, David F (2011) Chronology of the site of Grotte du Renne, Arcy-sur-Cure, France: implications for radiocarbon dating. Before Farm 2011(3):1–14, article 3

4 Issues of Chronological and Geographical Distributions of Middle and Upper Palaeolithic Cultural Variability in the Levant and Implications for the Learning Behavior of Neanderthals and *Homo sapiens*

Seiji Kadowaki

Abstract

This paper examines chronological and geographical cultural variability during the Middle and Upper Palaeolithic in the Levant, using part of the archaeological database covering a temporal range from ca. 300 to 20 kya and the geographic areas of Africa and Eurasia. This database has been constructed in order to organize archaeological data available from the time periods and geographic areas where *Homo sapiens* presumably emerged and dispersed with a replacement or assimilation of preceding populations, including Neanderthals. The purpose of this examination is to discuss research issues regarding the potential differences in learning behavior between Neanderthals and *Homo sapiens*, that are in line with the primary objectives of the research project entitled "Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning" (the RNMH project; Akazawa, 2012). Although theoretical links between learning strategies and patterns of cultural change are proposed on the basis of cultural evolutionary theory, an attempt to test this objective empirically with archaeological data entails a number of challenges. The paper addresses these problems through empirical examinations of chronological and geographic distributions of lithic industries.

Keywords

Chronology • Levant • Lithic industry • Middle Palaeolithic • Upper Palaeolithic

4.1 Introduction

4.1.1 Aims of the Study

This paper derives from one of the many archaeological workshop investigations conducted by the research project entitled "Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning" (the RNMH project; Akazawa 2012). The research group "A01" for this project has been compiling archaeological data relevant to the RNMH process with two purposes in mind. The first is to collect and organize updated material evidence regarding the RNMH in a comprehensive manner, and the second is to obtain insights into prehistoric learning behaviors through the observation of diachronic and geographic patterns of cultural variability (Nishiaki 2012). Using part of the archaeological database compiled since 2010 (i.e., the beginning of the RNMH project), this paper first examines chronological and geographical cultural variability during the Middle and Upper Palaeolithic (hereafter MP and UP respectively) in the Levant and then discusses some implications of this archaeological evidence on the anthropological processes that took place in the region.

S. Kadowaki (✉)
University Museum, Nagoya University, Chikusa-ku, Nagoya 464-8601, Japan
e-mail: kadowaki@num.nagoya-u.ac.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_4, © Springer Japan 2013

The temporal and spatial range covered by the database of this project is set from ca. 300 to 20 kya in Africa and Eurasia, that is broader than those directly related to the RNMH events per se. This is because our aim is not just to trace the timings and frontiers of the RNMH events on the a priori assumption that such anthropological events are directly reflected in archaeological records, but to organize archaeological data available from the time periods and geographic areas, where *Homo sapiens* presumably emerged and dispersed with replacement or assimilation of preceding populations, including Neanderthals. Because much remains to be clarified in the association between archaeological remains and hominin taxa, we put more emphasis in this study on the systematic presentation and assessment of archaeological data broadly related to the RNMH process rather than attempting to provide definitive archaeological answers to anthropological problems of the RNMH.

On the other hand, the broad temporal and spatial ranges (i.e. 300–20 kya in Africa and Eurasia) of our archaeological investigations are expected to provide us with sufficient data to examine diachronic changes and geographic shifts by *Homo sapiens* and other preceding hominins, particularly Neanderthals. This analysis is intended to discuss the feasibility of conducting archaeological research on potential differences in learning behaviors between Neanderthals and *Homo sapiens*, that is the primary objective of the RNMH project. Although theoretical links between learning strategies and patterns of cultural changes are proposed on the basis of cultural evolutionary theories (the research group "B01": Aoki 2012), an attempt for their empirical testing with archaeological data entails a number of challenges. First of all, archaeological remains that can be securely associated with hominin taxa are limited. Moreover, it is difficult to reliably assess the speed and cumulativeness of cultural changes, which are considered significant aspects in cultural evolutionary theories, because of numerous chronological issues and variable definitions of prehistoric cultures. Because these challenges cannot be readily resolved, the present study would rather address and clarify these problems through empirical examinations of chronological and geographic distributions of archaeological cultures. We will then propose parsimonious interpretations of the patterns of cultural changes during the MP and UP periods in terms of prehistoric learning behaviors as one of our contributions to the goals of the RNMH project.

4.1.2 Using the Lithic Industry as a Unit of Cultural Variability and a Proxy Measure of Prehistoric Learning: Reasons and Limitations

As a means to organize archaeological data and examine cultural patterns relevant to the RNMH, this study employs the concept of lithic industry as a fundamental feature of prehistoric cultures. There are two reasons for this. First, for almost any project dealing with broad temporal and spatial ranges, lithics are the only archaeological remains that are consistently available under various conditions and can provide a sufficient sample size to justify plausible interpretations. In fact, lithic technology constitutes the main descriptive features of Palaeolithic archaeology across wide regions, including those targeted in this project (e.g., Barham and Mitchell 2008; Dennel 2009; Hovers and Kuhn 2006). Second, recent definitions of lithic industries tend to be based on the concepts of patterned technological behaviors/choices, e.g., *chaîne opératoires*, in the course of lithic production activities rather than mere morphological similarity of finished products (e.g., Bar-Yosef 2003, pp. 268–270). Because such archaeologically recognizable patterns of technological behaviors/choices should have been socially shared, i.e., disseminated through social learning, it would be reasonable to expect that the patterns in the continuity or changes of lithic industries are primarily products of social communications, that are mediated by members who can also practice individual learning and/or exploratory individual learning strategies.

Although the concept of the lithic industry may be useful for the cultural-historical organization of archaeological data over broad temporal and spatial ranges, how reliable is the concept when analyses are directed towards the interpretation of prehistoric learning? For example, according to some cultural evolutionary models, learning strategies can affect the speed and rate of accumulation of cultural evolution (Borenstein et al. 2008). If one attempts to examine this model with archaeological data, the rate and accumulative nature of prehistoric culture change needs to be measured. Can this be accomplished by referring to cultural chronologies based on lithic industries? If so, how reliable are these measurements and interpretations? Additionally, if we are to compare learning behavior between *Homo sapiens* and Neanderthals by inferring them from cultural patterns, we have to identify lithic industries made by these two hominin groups respectively. How plausible are these links? These questions will be discussed in this paper, dealing with actual lithic data from the MP and UP of the Levant.

4.1.3 Construction of the Archaeological Database: *Neander DB*

Consistent with the above research questions and theoretical concerns, we designed our archaeological database, named *Neander DB*, to include four data sets (See the chapter by Kondo and Nishiaki in this volume for details). The first set is related to the archaeological sites and their specific geographic locations (i.e., longitude and latitude), and the site type (e.g., cave, rock shelter, or open-air). The second set includes various kinds of data on cultural layers, such as the name of the lithic industry, to which excavated assemblages are assigned, estimated ages, radiometric dates, the presence/absence of hominin fossils, and the presence/absence of non-lithic materials, particularly those indicative of modern human behaviors, e.g., bone tools and portable art. The third dataset describes technological characteristics of lithic industries that are included in the database, and finally the forth dataset is the bibliography of data sources (e.g., site reports and articles).

The collection of these data is mostly a result of a literature survey supplemented with unpublished data from our own fieldwork. To achieve efficient data collection and construction of the database on numerous sites over vast regions (i.e., Africa and Eurasia), and time periods, ca. 300–20 kya, we have employed a network-based database system, in which multiple researchers around the world can access the same database through the internet and cooperate in its construction (Kondo et al. 2012). In the past 2 years, about 2,000 archaeological sites have been entered into the database, and as described in the next section, data on ca.120 sites in the Levant have been used in the examination of MP and UP lithic industries.

4.2 Theoretical and Methodological Concerns Regarding the Lithic Industry Concept

4.2.1 Lithic Industries Examined in This Study

Table 4.1 and Fig. 4.1 show the list of lithic industries and their several recent chronological schemes dealt with in this study. The industries proposed by Bar-Yosef (1995) and Henry (2004) cover mainly the MP period, and that by Bar-Yosef (2000) ranges from the late MP to the UP. Chronologies of the Upper and early Epipalaeolithic industries have been organized by Goring-Morris (1995) and, more recently, by Belfer-Cohen and Goring-Morris (2003). Lithic industries that are widely recognized for the MP period in the Levant are Tabun D-type, Tabun C-type, and Tabun B-type industries, while the Levantine UP industries include the Initial Upper Palaeolithic (IUP or Emiran); Early Ahmarian; Levantine Aurignacian A; Classic Levantine Aurignacian; Atlitian; Arqov/Divshon; and Late Ahmarian. For the early Epipalaeolithic period, the Nebekian and Kebaran are examined in this study.

Table 4.1 List of lithic industries and some of archaeological sites examined in this study

	Lithic industries	Sites with hominin remains[a]	Some of other excavated or systematically surveyed sites[b]
Early Epipalaeolithic	Nebekian		Ain Qasiyya (Area D), Tor Hamar (E), Uwaynid 14 & 18, Jilat 6 (C), Yabrud III (6–7), Yutil Hasa (C, E)
	Kebaran	Ain Qasiyya (Area A&B), Ein Gev I, Kebara (C), Kharaneh IV (B)	Fazael III, Hayonim (Ca-Ce), Nahal Oren (9), Raqefet (I), Urkan el-Rubb II
Upper Palaeolithic	Arqov/Divshon		Boker BE (I), Boker C, EinAqev, Har Horesha I, Tor Fawaz?
	Atlitian	Nahal Ein Gev I	Antelias (I & II), el-Wad (C), Ksar Akil (6)
	Classic Levantine Aurignacian	el-Wad (D)	Antelias (III & IV), Hayonim (D), Kebara (I&II), Ksar Akil (7–8), Raqefet (III)
	Levantine Aurignacian A?		Ksar Akil (11–13), Umm el-Tlel
	Late Ahmarian (including Masraqan)	Ohalo II	Ain al-Buhayra (Unit C, F, and H-I), Ein Aqev East, Fazael X, Lagama X, Yutil al-Hasa (Areas A and B)
	Early Ahmarian	Ksal Akil (14–20) and Qafzeh (D)	Abu Noshra I, Boker A, Boker BE, Erq el-Ahmar (E-F), Jebel Humeima, Kebara (III-IV), Lagama VII, Thalab al-Buhayla, Tor Aeid, Tor Hamar (F-G), Yabrud II (5–6)
	Initial Upper Paleolithic (Emiran)	ÜçağızlıMughara?[c]	Boker Tachtit, KsarAkil (21–25), Tor Sadaf (A & B), Umm el-Tlel (IIbase& III2a'), WadiAghar
Middle Palaeolithic	Tabun B	Neanderthals from Amud (B 1&2), Dederiyeh (3, 11, & 13), Kebara (VII-XII), Shukba (D), and Tabun (C1)?[c]	Bezez (B), Erq el-Ahmar (H), Keoue, Sefunim, Tor Faraj, Tor Sabiha
	Tabun C	Qafzeh (XV-XXII), Skhul (B), Tabun (C2)?[c]	Dederiyeh (D), Douara (III), Hayonim (upper E), Naamé, Nahr Ibrahim, Ras el-Kelb
	Tabun D sensu lato		Abu Sif, Ain Difla, Dederiyeh (E), Douara (IV), Hayonim (lower E and F), Hummal (II), Jerf Ajla, Nahal Aqev, Rosh Ein Mor, Tabun (D), Yabrud I

[a]*Homo sapiens* unless indicated
[b]Layer numbers/alphabets are shown in parentheses following site names
[c]See discussions in the text

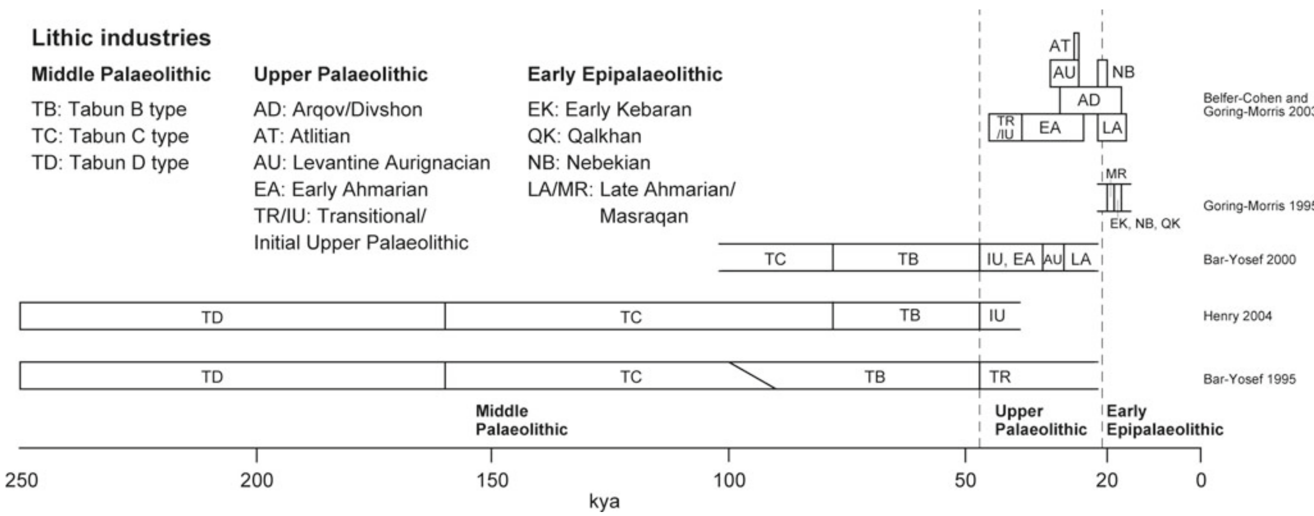


Fig. 4.1 Several chronological schemes of the Middle and Upper Palaeolithic industries in the Levant

The collection and organization of data on these lithic industries is not a straightforward task. It cannot be done by simply copying the contents of site reports because the study of lithic industries involves ongoing controversial issues. Additionally, various researchers do not always share the same views on the definition of lithic industries, their identification of actual lithic assemblages, and chronological relationships. To deal with this problem, it is necessary to distinguish current and widely accepted data from outdated ones regarding the definitions, identification, and chronology of lithic industries. Moreover, we built multiple models for the definition, identification, and/or chronology of some lithic industries when several different scenarios are conceivable or proposed by different researchers. The following section addresses these concerns before presenting the chronological and geographic analyses of lithic industries.

4.2.2 Definitions and Interpretations of Lithic Industries in the Levant

A lithic industry is defined by techno-morphological characteristics that are repetitively observable in multiple lithic assemblages, that are primary components of and provide material evidence to define and understand the lithic industry concept. A lithic assemblage is a collection of lithics usually defined by stratigraphy and/or context at archaeological sites. According to Marks (2003), who puts more emphasis on technological aspects rather than morphology, criteria for defining lithic industries include core reduction methods, the choice of blanks to be retouched, and retouch technology. The grouping and/or classification of lithic assemblages can be hierarchical depending on the degree of similarity. For example, Henry (1989, pp. 82–83) defines a phase/facies as a group of lithic assemblages sharing the highest degree of techno-morphological similarity. Phases/facies sharing similar techno-morphological traits are then grouped into the same industry, and similar industries are further grouped into the same complex. A lineage concept is proposed by Marks (2003, p. 251) to group lithic industries that are observable over a long time period and over wide areas with gradual variation. Both concepts of complex and lineage belong to categories in a higher hierarchical level than that of industry, and cover wider temporal and geographical ranges.

Among these several different classificatory levels, this study employs the concept of industry as a unit for analyzing the variability of lithic remains because the definition and identification of lithic industries are frequently discussed for the classification of lithic assemblages in the Levant as well as in other areas studied in the RNMH project. Additionally, an archaeological entity is also often mentioned as a temporal and spatial unit of material remains. This concept is applied to various material remains including more than lithics, but its level in the hierarchical classification appears to be similar to lithic industries (Belfer-Cohen and Goring-Morris 2003, pp. 2–9).

While the concept of a lithic industry is empirically based on lithic morphology and production technology, as described above, there is a great deal of controversy over what it represents. In the past few decades, a number of Levantine Palaeolithic studies examined diachronic and geographic variability in lithic technology in terms of climatic shifts (e.g., Jelinek 1981). Recent studies on the variability of MP and UP lithic assemblages also examine ecological factors, such as the distance to raw material sources and water, behaviors of raw material acquisition, duration of settlement, and hunting (Hovers 2009, pp. 207–223; Williams 2003).

On the other hand, this study considers social and cultural factors more relevant to the definition of lithic industries as the study is directed towards the interpretation of prehistoric learning and takes a theoretical position that a lithic industry is defined by patterned technological behaviors/choices that are disseminated among group members through social learning. For example, Hovers (2009, p. 227) suggests that the variability of MP lithic assemblages from Qafzeh Cave is principally organized by "technological tradition, embedded in the overall social system" rather than environmental or ecological factors. The technological tradition means socially and culturally patterned choices of technological behaviors that are not necessarily co-related with function or efficiency. A similar interpretation of a lithic industry is addressed by Marks (2003, p. 251) who suggests that technological characteristics that define lithic industries transcend the contents of activities or raw material availability at each site. In addition, Goring-Morris and Belfer-Cohen (2006, p. 308) criticize Williams' (2003, pp. 206–207) explanation on the technological difference between the Ahmarian and the flake-based assemblages in relation to the distance of sites from water sources. Instead, Goring-Morris and Belfer-Cohen (2006) suggest that Levantine Upper Palaeolithic industries, such as the Ahmarian, Classic Levantine Aurignacian, Arqov/Divshon, and Atlitian, correspond to different social groups or cultures, and propose the influx/replacement of populations or indigenous cultural changes as primary factors for the variability of lithic industries.

4.2.3 Some Issues on the Identification of Lithic Industries in the Levant

This section describes various issues on the identification of lithic industries and how they have affected the structure and meaning of actual lithic assemblages, and describes how this study deals with these problems in the construction of the *Neander DB* archaeological database.

4.2.3.1 Middle Palaeolithic

This study employs a widely recognized tripartite scheme, similar to that of the Tabun D/C/B types or Phases 1–3, for the MP industries in the Levant (Copeland 1975). The three industries are grouped under the Levantine Mousterian tradition, and their common use of the Levallois technique distinguishes them from the preceding Yabrudian complex. The Tabun D-type is characterized by the production of blades and elongated points both created using the Levallois method and the "laminar system." A significant number of Upper Palaeolithic tool types occur in the D-type assemblages. In contrast, unilateral side scrapers are representative of the Tabun C-type industry, that often produces oval flakes with some points and blades from centripetally and/or bidirectionally prepared Levallois cores. The Levallois cores of the Tabun B-type are frequently prepared by unidirectional convergent flaking that produces broad based points with some blades. Side scrapers dominate the retouched tool inventory with few Upper Palaeolithic types.

The identification of these industries in prehistoric lithic assemblages is primarily based on recent descriptions (e.g., Henry 2004; Shea 2003; Bar-Yosef 2000). When the same assemblage is assigned to different industries by different researchers, we adopt all the opinions in the database unless they are outdated in light of current evidence so that multiple scenarios can be examined without a priori selection of various interpretations. In addition, there are some assemblages whose techno-typological characteristics do not clearly fit any one of the three MP industries, such as those from Yabrud Rockshelter I and the el-Kowm basin including Umm el-Tlel. Although a single ESR date from Quneitra (No. 289 and 290 in Table 4.2) might suggest that it is contemporary with the Tabun B-type industry or Phase 3 (Ziaei et al. 1990), this chronological position is not corroborated on techno-typological grounds as I discuss later. The assemblages, named the Late Mousterian or Levalloiso-Mousterian in the el-Kowm basin, are stratigraphically located above the Hummalian, which is contemporary with the Tabun D type industry (Le Tensorer et al. 2008). Thus, the chronological position of the former may be close to the Tabun C-type or B-type industries.

4.2.3.2 Upper Palaeolithic and Early Epipalaeolithic

While the identification of lithic industries from these time periods has been traditionally based on the cultural sequence constructed by Neuville (1951), this study refers to recent terms and definitions.

The beginning of the UP is marked by the Initial Upper Palaeolithic (IUP or Emiran) industry that is technologically characterized by the introduction of prismatic cores and the production of pointed blades with relatively large, sometimes facetted, striking platforms. The IUP is also typologically defined by the high occurrences of Upper Palaeolithic tools (i.e., burins and end scrapers) with some fossil indices, such as Emireh points and chamfered pieces. Despite the accumulation of IUP assemblages at sites such as Boker Tachtit (Marks 1983); Ksar Akil XXI-XXV (Ohnuma 1988); Üçağızlı F-H (Kuhn et al. 2009); Wadi Aghar (Coinman and Henry 1995); and Tor Sadaf (Fox and Coinman 2004), the debate over their interpretations continues (Bar-Yosef and Belfer-Cohen 2010) with a view that this industry represents a transitional phase from the Middle to Upper Palaeolithic period, and an alternate position maintaining that the IUP culture was brought by *Homo sapiens* dispersing from Africa.

Discussions regarding the techno-typological variability of Upper Palaeolithic chipped stones following the IUP often refer to two cultural traditions, the Ahmarian and the Levantine Aurignacian (Marks 1981; Gilead 1981). The for-

Table 4.2 List of radiometric dates of Middle Palaeolithic sites in the Levant

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
1	Tabun Cave	Layer D	TL	T36	Burnt flint	276,000	29,000	29,000	
2	Tabun Cave	Layer D	TL	T23	Burnt flint	266,000	35,000	35,000	
3	Tabun Cave	Layer D	TL	Unit IX average (2003)	Burnt flint	256,000	18,000	18,000	O
4	Tabun Cave	Layer D	TL	T34	Burnt flint	248,000	27,000	27,000	
5	Tabun Cave	Layer D	TL	T33	Burnt flint	243,000	24,000	24,000	
6	Tabun Cave	Layer D	TL	T21	Burnt flint	237,000	29,000	29,000	
7	Tabun Cave	Layer D	TL	Unit V average (2003)	Burnt flint	222,000	36,000	36,000	O
8	Tabun Cave	Layer D	TL	T19	Burnt flint	215,000	23,000	23,000	
9	Tabun Cave	Layer D	TL	T25	Burnt flint	198,000	22,000	22,000	
10	Tabun Cave	Layer D	TL	Unit II average (2003)	Burnt flint	196,000	17,000	17,000	O
11	Tabun Cave	Layer D	TL	T18	Burnt flint	191,000	23,000	23,000	
12	Tabun Cave	Layer D	TL	T22	Burnt flint	188,000	22,000	22,000	
13	Tabun Cave	Layer D	TL	T20	Burnt flint	183,000	15,000	15,000	
14	Tabun Cave	Layer D	ESR EU	Revised average	Tooth	133,000	13,000	13,000	O
15	Tabun Cave	Layer D	ESR LU	Revised average	Tooth	203,000	26,000	26,000	O
16	Tabun Cave	Layer D	US/ESR	Revised average	Tooth	143,000	41,000	28,000	O
17	Tabun Cave	Layer D	U-series	556	Tooth	110,680	880	870	
18	Hayonim	F	TL	525	Burnt flint	251,000	20,000	20,000	
19	Hayonim	F	TL	50	Burnt flint	235,000	26,000	26,000	
20	Hayonim	F	TL	518	Burnt flint	233,000	20,000	20,000	
21	Hayonim	F	TL	522	Burnt flint	227,000	24,000	24,000	
22	Hayonim	F	TL	523	Burnt flint	225,000	41,000	41,000	
23	Hayonim	F	TL	57	Burnt flint	224,000	21,000	21,000	
24	Hayonim	F	TL	F top average	Burnt flint	221,000	16,000	16,000	O
25	Hayonim	F	TL	527	Burnt flint	221,000	22,000	22,000	
26	Hayonim	F	TL	F base average	Burnt flint	210,000	25,000	25,000	O
27	Hayonim	F	TL	516	Burnt flint	205,000	35,000	35,000	
28	Hayonim	F	TL	60	Burnt flint	204,000	17,000	17,000	
29	Hayonim	F	TL	519	Burnt flint	189,000	20,000	20,000	
30	Hayonim	F	TL	526	Burnt flint	187,000	20,000	20,000	
31	Hayonim	F	TL	524	Burnt flint	183,000	60,000	60,000	
32	Hayonim	F	TL	520	Burnt flint	175,000	22,000	22,000	
33	Hayonim	F	ESR EU	95,601 (E/F)	Tooth	158,000	20,000	20,000	O
34	Hayonim	F	ESR LU	95,601 (E/F)	Tooth	164,000	221,000	221,000	O
35	Hayonim	Lower E	TL	416	Burnt flint	208,000	35,000	35,000	
36	Hayonim	Lower E	TL	406	Burnt flint	202,000	28,000	28,000	
37	Hayonim	Lower E	TL	410	Burnt flint	200,000	29,000	29,000	
38	Hayonim	Lower E	TL	58	Burnt flint	197,000	18,000	18,000	
39	Hayonim	Lower E	TL	403	Burnt flint	194,000	28,000	28,000	
40	Hayonim	Lower E	TL	E base average	Burnt flint	186,000	24,000	24,000	O
41	Hayonim	Lower E	TL	Unit4 (north) average	Burnt flint	176,000	28,000	28,000	O
42	Hayonim	Lower E	TL	Unit4 (south) average	Burnt flint	168,000	27,000	27,000	O
43	Hayonim	Lower E	TL	417	Burnt flint	163,000	23,000	23,000	
44	Hayonim	Lower E	TL	414	Burnt flint	160,000	22,000	22,000	
45	Hayonim	Lower E	TL	Unit5 (south) average	Burnt flint	160,000	22,000	22,000	O
46	Hayonim	Lower E	TL	409	Burnt flint	159,000	13,000	13,000	
47	Hayonim	Lower E	TL	415	Burnt flint	157,000	19,000	19,000	

(continued)

Table 4.2 (continued)

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
48	Hayonim	Lower E	TL	401	Burnt flint	154,000	17,000	17,000	
49	Hayonim	Lower E	TL	402	Burnt flint	151,000	17,000	17,000	
50	Hayonim	Lower E	TL	418	Burnt flint	140,000	16,000	16,000	
51	Hayonim	Lower E	TL	412	Burnt flint	105,000	9,000	9,000	
52	Hayonim	Lower E	ESR EU	97,042	Tooth	200,000	32,000	32,000	O
53	Hayonim	Lower E	ESR EU	95,606	Tooth	177,000	32,000	32,000	O
54	Hayonim	Lower E	ESR EU	97,040	Tooth	172,000	33,000	33,000	O
55	Hayonim	Lower E	ESR EU	95,602	Tooth	160,000	28,000	28,000	O
56	Hayonim	Lower E	ESR EU	97,230	Tooth	158,000	28,000	28,000	O
57	Hayonim	Lower E	ESR EU	97,228	Tooth	150,000	21,000	21,000	O
58	Hayonim	Lower E	ESR EU	97,232	Tooth	142,000	30,000	30,000	O
59	Hayonim	Lower E	ESR EU	97,229	Tooth	136,000	25,000	25,000	O
60	Hayonim	Lower E	ESR LU	97,042	Tooth	211,000	35,000	35,000	O
61	Hayonim	Lower E	ESR LU	95,606	Tooth	182,000	34,000	34,000	O
62	Hayonim	Lower E	ESR LU	97,040	Tooth	175,000	33,000	33,000	O
63	Hayonim	Lower E	ESR LU	97,228	Tooth	164,000	26,000	26,000	O
64	Hayonim	Lower E	ESR LU	95,602	Tooth	160,000	28,000	28,000	O
65	Hayonim	Lower E	ESR LU	97,230	Tooth	159,000	28,000	28,000	O
66	Hayonim	Lower E	ESR LU	97,232	Tooth	143,000	30,000	30,000	O
67	Hayonim	Lower E	ESR LU	97,229	Tooth	136,000	25,000	25,000	O
68	Ain Difla	1–20	TL	Oxford	Burnt flint	105,000	15,000	15,000	O
69	Ain Difla	1–20	ESR EU	94,812	Tooth	114,900	14,200	14,200	O
70	Ain Difla	1–20	ESR EU	94816B	Tooth	112,500	14,600	14,600	O
71	Ain Difla	1–20	ESR EU	94814C	Tooth	95,800	12,000	12,000	O
72	Ain Difla	1–20	ESR EU	94816A	Tooth	88,300	11,500	11,500	O
73	Ain Difla	1–20	ESR LU	94816B	Tooth	185,600	26,600	26,600	O
74	Ain Difla	1–20	ESR LU	94,812	Tooth	165,700	20,500	20,500	O
75	Ain Difla	1–20	ESR LU	94814C	Tooth	154,700	21,300	21,300	O
76	Ain Difla	1–20	ESR LU	94816A	Tooth	142,800	20,700	20,700	O
77	Nahal Aqev	D at nearby fossil spring	U-series	76NZ6d-4	Travertine	85,200	10,000	10,000	O
78	Nahal Aqev	D at nearby fossil spring	U-series	76NZ1	Travertine	74,000	5,000	5,000	O
79	Jerf Ajla	Yellow 1	C14		Charcoal	43,000	2,000	2,000	
80	Douara Cave	Horizon IV	Fission-track		Barite from a Hearth	75,000			
81	Douara Cave	Unit IVB	C14	GrN-7599	Hearth ash	>52,000			
82	Douara Cave	Unit IVB	C14	TK-166	Hearth ash	>43,200			
83	Douara Cave	Unit IVB	C14	TK-167	Hearth ash	>43,200			
84	Douara Cave	Unit IVB	C14	TK-168	Hearth ash	>43,200			
85	Douara Cave	Unit IVB	C14	TK-165	Hearth ash	38,900	1,700	1,700	
86	Douara Cave	Layer E	C14	TK-111	Charcoal	45,000	5,000	5,000	
87	Douara Cave	Layer E	C14	GaK-3537	Charcoal	30,600	2,800	2,100	
88	Douara Cave	Layer E	C14	GaK-3539	Charcoal	20,400	750	750	
89	Douara Cave	Layer E	C14	GaK-3541	Charcoal	16,800	500	500	
90	Douara Cave	Layer D	C14	GaK-3540	Charcoal	19,850	550	550	
91	Tabun Cave	Layer C	TL	T5	Burnt flint	195,000	18,000	18,000	
92	Tabun Cave	Layer C	TL	T14	Burnt flint	179,000	16,000	16,000	
93	Tabun Cave	Layer C	TL	T13	Burnt flint	175,000	18,000	18,000	
94	Tabun Cave	Layer C	TL	T10	Burnt flint	172,000	17,000	17,000	
95	Tabun Cave	Layer C	TL	T9	Burnt flint	168,000	17,000	17,000	
96	Tabun Cave	Layer C	TL	Unit I average (2003)	Burnt flint	165,000	23,000	23,000	O
97	Tabun Cave	Layer C	TL	T8	Burnt flint	139,000	14,000	14,000	

(continued)

Table 4.2 (continued)

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
98	Tabun Cave	Layer C	TL	T15	Burnt flint	128,000	14,000	14,000	
99	Tabun Cave	Layer C	ESR EU	Revised average	Tooth	120,000	16,000	16,000	O
100	Tabun Cave	Layer C	ESR LU	Revised average	Tooth	140,000	21,000	21,000	O
101	Tabun Cave	Layer C	US/ESR	Revised average	Tooth	135,000	60,000	30,000	O
102	Tabun Cave	Layer C	U-series	552	Tooth	105,360	2,580	2,520	O
103	Tabun Cave	Layer C	U-series	551	Tooth enamel	101,690	1,360	1,340	O
104	Tabun Cave	Layer C	U-series	551	Tooth	97,840	430	420	O
105	Hayonim	Upper E	TL	75	Burnt flint	178,000	29,000	29,000	
106	Hayonim	Upper E	TL	76	Burnt flint	169,000	17,000	17,000	
107	Hayonim	Upper E	TL	68	Burnt flint	163,000	19,000	19,000	
108	Hayonim	Upper E	TL	65	Burnt flint	162,000	22,000	22,000	
109	Hayonim	Upper E	TL	Unit2 (south) average	Burnt flint	156,000	10,000	10,000	O
110	Hayonim	Upper E	TL	Unit3 (south) average	Burnt flint	156,000	18,000	18,000	O
111	Hayonim	Upper E	TL	23	Burnt flint	155,000	19,000	19,000	
112	Hayonim	Upper E	TL	84	Burnt flint	155,000	16,000	16,000	
113	Hayonim	Upper E	TL	67	Burnt flint	149,000	15,000	15,000	
114	Hayonim	Upper E	TL	10	Burnt flint	148,000	18,000	18,000	
115	Hayonim	Upper E	TL	20	Burnt flint	146,000	13,000	13,000	
116	Hayonim	Upper E	TL	11	Burnt flint	146,000	13,000	13,000	
117	Hayonim	Upper E	TL	3	Burnt flint	144,000	16,000	16,000	
118	Hayonim	Upper E	TL	80	Burnt flint	144,000	17,000	17,000	
119	Hayonim	Upper E	TL	Unit3 (north) average	Burnt flint	144,000	3,000	3,000	O
120	Hayonim	Upper E	TL	7	Burnt flint	143,000	14,000	14,000	
121	Hayonim	Upper E	TL	4	Burnt flint	142,000	13,000	13,000	
122	Hayonim	Upper E	TL	5	Burnt flint	140,000	11,000	11,000	
123	Hayonim	Upper E	TL	26	Burnt flint	139,000	13,000	13,000	
124	Hayonim	Upper E	TL	61	Burnt flint	129,000	11,000	11,000	
125	Hayonim	Upper E	TL	Unit2 (north) average	Burnt flint	129,000	12,000	12,000	O
126	Hayonim	Upper E	TL	82	Burnt flint	128,000	14,000	14,000	
127	Hayonim	Upper E	TL	24	Burnt flint	127,000	14,000	14,000	
128	Hayonim	Upper E	TL	21	Burnt flint	126,000	12,000	12,000	
129	Hayonim	Upper E	TL	63	Burnt flint	125,000	13,000	13,000	
130	Hayonim	Upper E	TL	25	Burnt flint	125,000	12,000	12,000	
131	Hayonim	Upper E	TL	27	Burnt flint	124,000	12,000	12,000	
132	Hayonim	Upper E	TL	22	Burnt flint	119,000	12,000	12,000	
133	Hayonim	Upper E	TL	9	Burnt flint	119,000	10,000	10,000	
134	Hayonim	Upper E	TL	62	Burnt flint	114,000	15,000	15,000	
135	Hayonim	Upper E	ESR EU	95,603	Tooth	183,000	28,000	28,000	O
136	Hayonim	Upper E	ESR EU	94,902	Tooth	180,000	27,000	27,000	O
137	Hayonim	Upper E	ESR EU	95,605	Tooth	178,000	21,000	21,000	O
138	Hayonim	Upper E	ESR EU	94,901	Tooth	176,000	30,000	30,000	O
139	Hayonim	Upper E	ESR EU	94,881	Tooth	163,000	26,000	26,000	O
140	Hayonim	Upper E	ESR LU	95,603	Tooth	191,000	31,000	31,000	O
141	Hayonim	Upper E	ESR LU	94,902	Tooth	190,000	30,000	30,000	O
142	Hayonim	Upper E	ESR LU	95,605	Tooth	187,000	23,000	23,000	O
143	Hayonim	Upper E	ESR LU	94,901	Tooth	182,000	32,000	32,000	O
144	Hayonim	Upper E	ESR LU	94,881	Tooth	164,000	26,000	26,000	O
145	Hayonim	Upper E	U-series	94,902	Tooth	156,400	9,800	9,000	O
146	Hayonim	Upper E	U-series	95,605	Tooth	117,300	900	900	O
147	Qafzeh Cave	Layer XXIII	TL	76	Burnt flint	95,000	7,700	7,700	O

(continued)

Table 4.2 (continued)

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
148	Qafzeh Cave	Layer XXII	TL	66	Burnt flint	91,200	8,700	8,700	O
149	Qafzeh Cave	Layer XXII	TL	65	Burnt flint	86,600	7,400	7,400	O
150	Qafzeh Cave	Layer XXII	TL	67	Burnt flint	85,400	6,900	6,900	O
151	Qafzeh Cave	Layer XXI	TL	1	Burnt flint	109,900	9,900	9,900	O
152	Qafzeh Cave	Layer XXI	TL	61	Burnt flint	90,900	8,700	8,700	O
153	Qafzeh Cave	Layer XXI	TL	2	Burnt flint	89,200	8,900	8,900	O
154	Qafzeh Cave	Layer XXI	ESR EU	369B	Tooth	118,000			O
155	Qafzeh Cave	Layer XXI	ESR EU	369A	Tooth	95,900			O
156	Qafzeh Cave	Layer XXI	ESR EU	369E	Tooth	95,300			O
157	Qafzeh Cave	Layer XXI	ESR EU	369D	Tooth	74,200			O
158	Qafzeh Cave	Layer XXI	ESR EU	369C	Tooth	73,700			O
159	Qafzeh Cave	Layer XXI	ESR LU	369B	Tooth	143,000			O
160	Qafzeh Cave	Layer XXI	ESR LU	369A	Tooth	118,000			O
161	Qafzeh Cave	Layer XXI	ESR LU	369E	Tooth	116,000			O
162	Qafzeh Cave	Layer XXI	ESR LU	369C	Tooth	94,000			O
163	Qafzeh Cave	Layer XXI	ESR LU	369D	Tooth	89,100			O
164	Qafzeh Cave	Layer XIX	TL	45	Burnt flint	98,800	8,900	8,900	O
165	Qafzeh Cave	Layer XIX	TL	77	Burnt flint	95,900	8,100	8,100	O
166	Qafzeh Cave	Layer XIX	TL	49	Burnt flint	84,900	7,300	7,300	O
167	Qafzeh Cave	Layer XIX	TL	47	Burnt flint	82,400	7,700	7,700	O
168	Qafzeh Cave	Layer XIX	ESR EU	371B	Tooth	119,000			O
169	Qafzeh Cave	Layer XIX	ESR EU	368D	Tooth	111,000			O
170	Qafzeh Cave	Layer XIX	ESR EU	371A	Tooth	107,000			O
171	Qafzeh Cave	Layer XIX	ESR EU	368C	Tooth	102,000			O
172	Qafzeh Cave	Layer XIX	ESR EU	368B	Tooth	99,700			O
173	Qafzeh Cave	Layer XIX	ESR EU	368A	Tooth	87,700			O
174	Qafzeh Cave	Layer XIX	ESR EU	371C	Tooth	82,000			O
175	Qafzeh Cave	Layer XIX	ESR LU	371B	Tooth	145,000			O
176	Qafzeh Cave	Layer XIX	ESR LU	371A	Tooth	128,000			O
177	Qafzeh Cave	Layer XIX	ESR LU	368D	Tooth	124,000			O
178	Qafzeh Cave	Layer XIX	ESR LU	368C	Tooth	117,000			O
179	Qafzeh Cave	Layer XIX	ESR LU	368B	Tooth	112,000			O
180	Qafzeh Cave	Layer XIX	ESR LU	368A	Tooth	106,000			O
181	Qafzeh Cave	Layer XIX	ESR LU	371C	Tooth	101,000			O
182	Qafzeh Cave	Layer XIX	U-series	368	Tooth	106,350	2,360	2,310	O
183	Qafzeh Cave	Layer XIX	U-series	371	Tooth enamel	88,610	3,240	3,120	O
184	Qafzeh Cave	Layer XVIII	TL	42	Burnt flint	93,400	8,200	8,200	O
185	Qafzeh Cave	Layer XVIII	TL	40	Burnt flint	89,500	7,000	7,000	O
186	Qafzeh Cave	Layer XVIII	TL	38	Burnt flint	87,900	7,200	7,200	O
187	Qafzeh Cave	Layer XVII	TL	29	Burnt flint	107,200	8,800	8,800	O
188	Qafzeh Cave	Layer XVII	TL	14	Burnt flint	106,000	9,600	9,600	O
189	Qafzeh Cave	Layer XVII	TL	36	Burnt flint	100,700	8,200	8,200	O
190	Qafzeh Cave	Layer XVII	TL	13	Burnt flint	94,300	8,800	8,800	O
191	Qafzeh Cave	Layer XVII	TL	33	Burnt flint	89,200	8,400	8,400	O
192	Qafzeh Cave	Layer XVII	TL	34	Burnt flint	87,800	7,200	7,200	O
193	Qafzeh Cave	Layer XVII	ESR EU	372	Tooth	95,200			O
194	Qafzeh Cave	Layer XVII	ESR LU	372	Tooth	103,000			O
195	Qafzeh Cave	Layer XV	ESR EU	373	Tooth	94,700			O
196	Qafzeh Cave	Layer XV	ESR EU	370B	Tooth	94,200			O
197	Qafzeh Cave	Layer XV	ESR EU	370A	Tooth	92,100			O
198	Qafzeh Cave	Layer XV	ESR LU	373	Tooth	116,000			O
199	Qafzeh Cave	Layer XV	ESR LU	370B	Tooth	114,000			O
200	Qafzeh Cave	Layer XV	ESR LU	370A	Tooth	112,000			O
201	Skhul	Layer B	TL	Average	Burnt flint	119,000	18,000	18,000	O
202	Skhul	Layer B	ESR EU	521d	Tooth	101,000	19,000	19,000	

(continued)

Table 4.2 (continued)

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
203	Skhul	Layer B	ESR EU	521c	Tooth	94,900	15,600	15,600	
204	Skhul	Layer B	ESR EU	521a	Tooth	88,100	17,900	17,900	
205	Skhul	Layer B	ESR EU	521b	Tooth	86,100	13,100	13,100	
206	Skhul	Layer B	ESR EU	Average (1989)	Tooth	81,000	15,000	15,000	O
207	Skhul	Layer B	ESR EU	522b	Tooth	73,000	7,000	7,000	
208	Skhul	Layer B	ESR EU	522a	Tooth	68,000	5,400	5,400	
209	Skhul	Layer B	ESR EU	522c	Tooth	54,600	10,300	10,300	
210	Skhul	Layer B	ESR LU	521d	Tooth	119,000	25,100	25,100	
211	Skhul	Layer B	ESR LU	521c	Tooth	109,000	20,500	20,500	
212	Skhul	Layer B	ESR LU	521a	Tooth	102,000	22,700	22,700	
213	Skhul	Layer B	ESR LU	521b	Tooth	102,000	18,000	18,000	
214	Skhul	Layer B	ESR LU	Average (1989)	Tooth	101,000	12,000	12,000	O
215	Skhul	Layer B	ESR LU	522b	Tooth	99,900	12,400	12,400	
216	Skhul	Layer B	ESR LU	522a	Tooth	98,300	10,600	10,600	
217	Skhul	Layer B	ESR LU	522c	Tooth	77,200	15,700	15,700	
218	Skhul	Layer B	U-series	521	Tooth	80,270	550	550	
219	Skhul	Layer B	U-series	856-2	Tooth	45,530	740	730	
220	Skhul	Layer B	U-series	856-1	Tooth	43,460	140	140	
221	Skhul	Layer B	U-series	854	Tooth	43,030	470	460	
222	Skhul	Layer B	U-series	854	Tooth	41,410	390	380	
223	Skhul	Layer B	U-series	522	Tooth	40,430	210	210	
224	Naamé	Vermet	U-series			90,000	10,000	10,000	O
225	Naamé	Strombus	U-series			93,000	5,000	5,000	O
226	Naamé	Strombus	U-series			90,000	20,000	20,000	O
227	Tabun Cave	Layer B	ESR EU	Revised average	Tooth	102,000	17,000	17,000	O
228	Tabun Cave	Layer B	ESR LU	Revised average	Tooth	122,000	16,000	16,000	O
229	Tabun Cave	Layer B	US/ESR	Revised average	Tooth	104,000	33,000	18,000	O
230	Tabun Cave	Layer B	U-series	550DE	Tooth	50,690	230	230	
231	Amud Cave	B4	TL	51	Burnt flint	75,900	5,300	5,300	
232	Amud Cave	B4	TL	49	Burnt flint	70,800	3,800	3,800	
233	Amud Cave	B4	TL	52	Burnt flint	66,900	4,900	4,900	
234	Amud Cave	B4	TL	46	Burnt flint	64,700	4,000	4,000	
235	Amud Cave	B4	TL	47	Burnt flint	55,600	4,400	4,400	
236	Amud Cave	B4	TL	average	Burnt flint	68,500	3,400	3,400	O
237	Amud Cave	B4	ESR EU	95504am	Tooth	112,000	18,000	18,000	
238	Amud Cave	B4	ESR EU	95501-2ak	Tooth	68,000	10,000	10,000	
239	Amud Cave	B4	ESR LU	95504am	Tooth	115,000	19,000	19,000	
240	Amud Cave	B4	ESR LU	95501-2ak	Tooth	73,000	12,000	12,000	
241	Amud Cave	B4	MSUS/ESR	95504Den1	Tooth	113,000	18,000	18,000	
242	Amud Cave	B4	MSUS/ESR	95504Den2	Tooth	113,000	18,000	18,000	
243	Amud Cave	B4	MSUS/ESR	95501-2Den	Tooth	70,000	11,000	11,000	O
244	Amud Cave	B2	TL	27	Burnt flint	59,500	4,500	4,500	
245	Amud Cave	B2	TL	26	Burnt flint	55,400	4,000	4,000	
246	Amud Cave	B2	TL	10	Burnt flint	53,100	5,500	5,500	
247	Amud Cave	B2	TL	32	Burnt flint	52,700	5,500	5,500	
248	Amud Cave	B2	TL	62	Burnt flint	52,400	6,800	6,800	
249	Amud Cave	B2	TL	63	Burnt flint	45,600	3,000	3,000	
250	Amud Cave	B2	TL	13	Burnt flint	44,500	3,900	3,900	
251	Amud Cave	B2	TL	64	Burnt flint	44,100	3,100	3,100	
252	Amud Cave	B2	TL	Average	Burnt flint	56,500	3,500	3,500	O
253	Amud Cave	B2	ESR EU	95507alk	Tooth	66,000	8,000	8,000	
254	Amud Cave	B2	ESR EU	95508alk	Tooth	54,000	7,000	7,000	
255	Amud Cave	B2	ESR EU	95506alk	Tooth	51,000	5,000	5,000	
256	Amud Cave	B2	ESR LU	95507alk	Tooth	77,000	11,000	11,000	
257	Amud Cave	B2	ESR LU	95506alk	Tooth	65,000	8,000	8,000	

(continued)

Table 4.2 (continued)

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
258	Amud Cave	B2	ESR LU	95508alk	Tooth	63,000	9,000	9,000	
259	Amud Cave	B2	MSUS/ESR	95507Den1	Tooth	70,000	10,000	10,000	
260	Amud Cave	B2	MSUS/ESR	Average	Tooth	61,000	9,000	9,000	O
261	Amud Cave	B2	MSUS/ESR	95508Den1	Tooth	59,000	8,000	8,000	
262	Amud Cave	B2	MSUS/ESR	95506Den1	Tooth	53,000	7,000	7,000	
263	Amud Cave	B1	TL	12	Burnt flint	70,600	6,900	6,900	
264	Amud Cave	B1	TL	37	Burnt flint	61,300	5,200	5,200	
265	Amud Cave	B1	TL	38	Burnt flint	59,400	5,100	5,100	
266	Amud Cave	B1	TL	41	Burnt flint	58,100	4,100	4,100	
267	Amud Cave	B1	TL	40	Burnt flint	51,600	3,700	3,700	
268	Amud Cave	B1	TL	11	Burnt flint	49,000	4,600	4,600	
269	Amud Cave	B1	TL	Average	Burnt flint	57,600	3,700	3,700	O
270	Amud Cave	B1	ESR EU	95505alk	Tooth	50,000	6,000	6,000	
271	Amud Cave	B1	ESR LU	95505alk	Tooth	57,000	8,000	8,000	
272	Amud Cave	B1	MSUS/ESR	95505Den1	Tooth	53,000	7,000	7,000	O
273	Kebara	Layer XII	TL	Average	Burnt flint	59,900	3,500	3,500	O
274	Kebara	Layer XI	TL	Average	Burnt flint	60,000	3,500	3,500	O
275	Kebara	Layer X	TL	Average	Burnt flint	61,600	3,600	3,600	O
276	Kebara	Layer X	ESR EU	Average	Tooth enamel	60,400	5,900	5,900	O
277	Kebara	Layer X	ESR LU	Average	Tooth enamel	64,300	5,500	5,500	O
278	Kebara	Layer IX	TL	Average	Burnt flint	58,400	4,000	4,000	O
279	Kebara	Layer VIII	TL	Average	Burnt flint	57,300	4,000	4,000	O
280	Kebara	Layer VII	TL	Average	Burnt flint	51,900	3,500	3,500	O
281	Kebara	Layer VI	TL	Average	Burnt flint	48,300	3,500	3,500	O
282	Tor Sabiha	Layer C	AAR	AAL-5736	Ostrich eggshell	69,000	6,000	6,000	O
283	Tor Faraj	Layer C	TL		Burnt flint	52,800	3,000	3,000	O
284	Tor Faraj	Layer C	TL		Burnt flint	47,500	3,000	3,000	O
285	Tor Faraj	Layer C	TL		Burnt flint	43,800	2,000	2,000	O
286	Tor Faraj	Layer C	U-series		Ostrich eggshell	62,400	14,000	14,000	O
287	Tor Faraj	Layer C	U-series		Ostrich eggshell	28,900	3,900	3,900	
288	Tor Faraj	Layer C	AAR	AAL-5739	Ostrich eggshell	69,000	6,000	6,000	O
289	Quneitra	Un-stratified	ESR EU		Tooth	39,200			
290	Quneitra	Un-stratified	ESR LU		Tooth	53,900	1,700	1,700	O
291	Ksar Akil	27A	U-series	G-8881777S	Animal Bone	51,000	4,000	4,000	O
292	Ksar Akil	27A	U-series	G-888178	Animal Bone	49,000	5,000	5,000	O
293	Ksar Akil	26A	U-series	G-888174S	Animal bone	47,000	9,000	9,000	O
294	Ksar Akil	26A	U-series	G-888173B	Animal bone	19,000	5,000	5,000	
295	Ksar Akil	26A	C14-AMS	GrN-2579	Dark clay	43,750	1,500	1,500	
296	Far'ah II	Floor 1	ESR EU	95368A	Tooth	54,400	3,200	3,200	
297	Far'ah II	Floor 1	ESR EU	95370A	Tooth	50,100	3,100	3,100	
298	Far'ah II	Floor 1	ESR EU	Mean	Tooth	49,100	4,100	4,100	O
299	Far'ah II	Floor 1	ESR EU	95367A	Tooth	46,200	2,700	2,700	
300	Far'ah II	Floor 1	ESR EU	95,366	Tooth	45,600	2,700	2,700	
301	Far'ah II	Floor 1	ESR LU	95368A	Tooth	72,000	4,900	4,900	
302	Far'ah II	Floor 1	ESR LU	95370A	Tooth	62,700	4,700	4,700	
303	Far'ah II	Floor 1	ESR LU	Mean	Tooth	62,200	7,000	7,000	O
304	Far'ah II	Floor 1	ESR LU	95,366	Tooth	57,100	4,100	4,100	
305	Far'ah II	Floor 1	ESR LU	95367A	Tooth	57,100	4,100	4,100	
306	Far'ah II	Floor 1	U-series	95367A	Tooth enamel	74,500	1,500	1,500	O
307	Douara Cave	Horizon III	C14	GrN-8058	Ostrich eggshell	>53,800			

mer appeared earlier, following the IUP, and is dominated by the production of blades/bladelets that are modified into pointed or backed forms. In contrast, the beginning of the Levantine Aurignacian is dated to at least a few millennia later, and it is characterized by numerous flakes fashioned into burins and scrapers, and high occurrences of twisted bladelets detached from carinated tools/cores.

It is generally recognized that the Ahmarian is part of a technological complex whose autochthonous evolution can be traced from the IUP through the Early Ahmarian to the Late Ahmarian (Goring-Morris and Belfer-Cohen 2006, p. 308; Belfer-Cohen and Goring-Morris 2007, pp. 200–201). This local technological tradition, characterized by blade production, is named the "Levantine Leptolithic Lineage" by Marks (2003, p. 253). The Late Ahmarian is characterized by the increase of Ouchtata bladelets replacing el-Wad points, as well as the employment of multiple core-reduction strategies for bladelet production (Ferring 1988; Belfer-Cohen and Goring-Morris 2003; Coinman 2003; Marks 2003). In addition, some of the Late Ahmarian assemblages, such as Ohalo II and Fazael X, include microlith types, such as micropoints, obliquely truncated backed bladelets, and proto-triangles, that are hallmarks of the Kebaran, one of the early Epipalaeolithic entities (Nadel 2003), indicating the continuity of the Levantine Leptolithic lineage from the beginning of the UP to the early Epipalaeolithic period. It is, however, debatable if this apparent technological continuity represents that of local populations, and in turn any "accumulative cultural changes."

The variations within the Levantine Aurignacian have been traditionally grouped into Phases A, B, and C on the basis of stratified assemblages from Ksar Akil layers VI-XIII (Bergman 2003; Williams and Bergman 2010). Among the three phases, part of the Levantine Aurignacian B and C (i.e., layers VII and VIII) shows "classic" Aurignacian elements, such as flat frontally carinated and nosed scrapers along with bone and antler artifacts, such as split-based points, similar to the European Aurignacian. Belfer-Cohen and Goring-Morris (2003) re-define the Levantine Aurignacian by restricting it to the assemblages with "classic" Aurignacian characteristics, excluding some flake-based assemblages from the Aurignacian tradition and classifying them into separate industries, such as the Arqov/Divshon or the Atlitian.

However, there are some assemblages that are not included in the Levantine Aurignacian sensu stricto but remain to be assigned to any of other industries, such as those from Ksar Akil layer IX-XIII (Bergman 2003). According to Copeland (2003, p. 246), the assemblages from Ksar Akil XI-XIII should be placed within the Levantine Aurignacian A industry, to which UP assemblages from Kebara Unit I-II and Umm el-Tlel can also be assigned. A similar view is proposed by Olszewski and Dibble (2006, p. 363), who suggest that the high occurrence of blades in the Levantine Aurignacian A assemblages also characterizes the Zagros Aurignacian industry, that is typified by the assemblages from Warwasi layer P-Z. On the other hand, Belfer-Cohen and Goring-Morris (2003, p. 274) class the UP assemblages from Umm el-Tlel as the Late Ahmarian instead of the Levantine Aurignacian, and the Aurignacian assemblages from Kebara (Bar-Yosef et al. 1996) are included in the Classic Levantine Aurignacian instead of the Levantine Aurignacian A (Goring-Morris and Belfer-Cohen 2006, p. 311). In addition, a recent study of the UP assemblages from Umm el-Tlel suggests that some assemblages show technological characteristics of the late Ahmarian, while others show core-reduction technology indicative of the Aurignacian (Ploux and Soriano 2003). Interestingly, these assemblages of apparently different technological traditions are interstratified at Umm el-Tlel. In this way, there are ongoing issues and various positions regarding the definition of the Levantine Aurignacian and its identification in excavated lithic assemblages. These alternative perspectives are considered in this study by organizing them within the database.

In contrast to the Ahmarian, that is generally recognized as representing part of the endemic technological tradition in the Levant, the Levantine Aurignacian is usually interpreted to have been brought by foreign groups outside of the Levant (Bar-Yosef 2000, p. 136; Gilead 1995, p. 137; Marks 2003, p. 256). An ongoing debate on the origin of the Levantine Aurignacian appears to hinge on what is defined as "the Aurignacian" (Goring-Morris and Belfer-Cohen 2006, p. 308; Olszewski and Dibble 2006). While the Classic Levantine Aurignacian, typified by Ksar Akil VII-VIII, is comparable to the Aurignacian I in Europe, the claimed similarity between the Levantine Aurignacian A (including the assemblages of Ksar Akil XI-XII and Umm et-Tlel) and the Warwasi P-Z assemblages (Olszewski 2009) is not as clear. Goring-Morris and Belfer-Cohen (2006) further suggest that the occurrence of other flake-based industries (i.e., the Arqov/Divshon and Atlitian) are also likely to represent the influx of populations with different cultural traditions.

As for the Nebekian industry in the early Epipalaeolithic, this study adopts its recent definition and identification proposed by Olszewski (2006; 2008) that incorporates some assemblages, formerly named the Qalkhan industry (Henry 1995, pp. 215–242), as part of the Nebekian. The recent identification of the Nebekian also includes some assemblages that were once reported as the Kebaran, such as Wadi Hammeh 26, 31, and 33, because of the presence of the microburin technique that characterizes the Nebekian (Olszewski 2008).

On the basis of the above understandings of lithic industries as units for the examination of cultural variability, we now present chronological and geographical patterns of lithic industries during the Middle and Upper Palaeolithic in the Levant.

4.3 Chronological Examination of the Middle and Upper Palaeolithic Industries

4.3.1 Middle Palaeolithic

Although the Tabun B-, C-, and D- type industries were originally recognized at Tabun Cave as a stratigraphic sequence of three assemblages from Layers B, C, and D from the top to the bottom, the same stratigraphic occurrence is observable at only a few sites, such as Hayonim Cave (the D-type in layers F and the lower part of layer E, followed by the C-type in the upper layer of E), and probably Douara Cave (the D-type in Unit IV followed by the C-type in Unit III: Akazawa 1974). As such, the current scheme of the Levantine MP chronology primarily draws upon radiometric dating methods, e.g., TL, ESR, U-series, Amino acid racemization (AAR), and radiocarbon (for the youngest MP: Rebollo et al. 2011), that have been applied to these sites, including Tabun, Hayonim, 'Ain Difla, Rosh Ein Mor, Qafzeh, Skhul, Naamé, Kebara, Amud, Tor Faraj, Tor Sabiha, Quneitra, Ksar Akil, and Far'ah II.

We collected 307 radiometric dates from 40 cultural layers at 16 sites from published data (Table 4.2). Among these datasets, radiocarbon dates cannot be used as reliable age estimations because the temporal range of the MP is beyond the limit of this dating method (except for the youngest MP: Rebollo et al. 2011). Thus, 288 dates by either TL, ESR, U-series, and AAR are considered in the following discussions. Figure 4.2 shows the distribution of these radiometric dates by cultural layer that are then grouped into Tabun D-, C-, and B-type industries. Although recently reported radiocarbon dates for the youngest MP at Kebara, associated with the Tabun B-type assemblages (Unit V: Rebollo et al. 2011), are not included in Table 4.2, they are taken into account in the following discussions.

The overall pattern indicates that the three industries occurred in a general order from the Tabun D- through C- to B-type between ca. 250/200 and 50/45 kya. Although several dating results might suggest temporal overlap between different industries, they are not sufficient to replace the sequential model that is consistent with the stratigraphic evidence mentioned above. For example, some dates from 'Ain Difla (Clark et al. 1997) and Nahal Aqev (Schwarcz et al. 1979) might indicate that the Tabun D-type industry lasted longer in the southern arid areas, while it was replaced by the Tabun C-type in the north. However, if the error intervals are taken into account, the age estimations range widely between 90 and 180 kya for the former site (Clark et al. 1997, p. 91), while the dates of the latter site were actually obtained from travertine at the fossil spring 150 m away from the site (Schwarcz et al. 1979, p. 559). In addition, ESR dates (ca. 164–191 kya) for upper layer E at Hayonim Cave look anomalous in comparison with other dates for Tabun C-type assemblages (ca. 80–140 kya), as seen at Qafzeh, Skhul, Tabun layer C, and Naamé.

As for the dates of the Tabun B-type assemblages, revised ESR dates for Tabun layer B (ca. 100–120 kya: Grün and Stringer 2000) are anomalous, being closer to the dates of the Tabun C-type assemblages at Qafzeh and Skhul than those of other Tabun B sites, such as Kebara (Valladas et al. 1987) and Amud (Valladas et al. 1999). Thus, these revised ESR dates of Tabun layer B are not congruent with regional chrono-cultural patterns and require additional examples or further explanations to be accepted as reliable evidence. Otherwise, the dates of the Tabun B-type industry range between ca. 50/45 kya and 75 kya. Although this temporal range encompasses ESR dates from Quneitra and Far'ah II, the lithic assemblages from these sites do not show technological characteristics of the Tabun B-type industry (Shea 2003, p. 337). In fact, the dominance of flake forms in the Levallois products as well as the frequent employment of centripetal flaking in core-reduction at Quneitra (Goren-Inbar 1990) are more indicative of the Tabun C-type industry. This cultural attribution also explains the recovery of a flint flake with incised concentric lines from Quneitra because a stone tool with incised lines was also recovered in association with the Tabun C-type assemblages at Qafzeh (d'Errico et al. 2003).

U-series dates from Ksar Akil layers XXVI and XXVII, obtained many years ago, are in the temporal range of the Tabun B-type although the validity of these dates has not been further tested (van der Plicht and van der Wijk 1989). Some researchers find the assemblages from these layers similar to the Tabun C-type industry (Bar-Yosef 2000, p. 116; Shea 2003, p. 336). However, the stratigraphic changes in lithic technology from layers XXVIII to XXVI, i.e., an increase of the ovoid-shape Levallois products and a decrease of the converging form, is similar to those of Tabun-B assemblages from Unit XII to VII at Kebara, i.e., an increase of Levallois flakes and centripetal flaking in contrast to a decrease of unidirectional convergent flaking that produces Levallois points (Marks and Volkman 1986; Meignen and Bar-Yosef 1992).

In addition to the radiometric dates, the faunal sequence has contributed to the definition and construction of the Middle Palaeolithic chronology outlined here. For example, faunal assemblages, particularly micromammals, from layers XV-XXV of Qafzeh, associated with the Tabun C-type assemblages, are characterized by an increase in Afro-Arabian fauna adapted to savanna conditions (Tchernov 1998, pp. 84–85). This is interpreted to represent a northward expansion of Afro-Arabian species

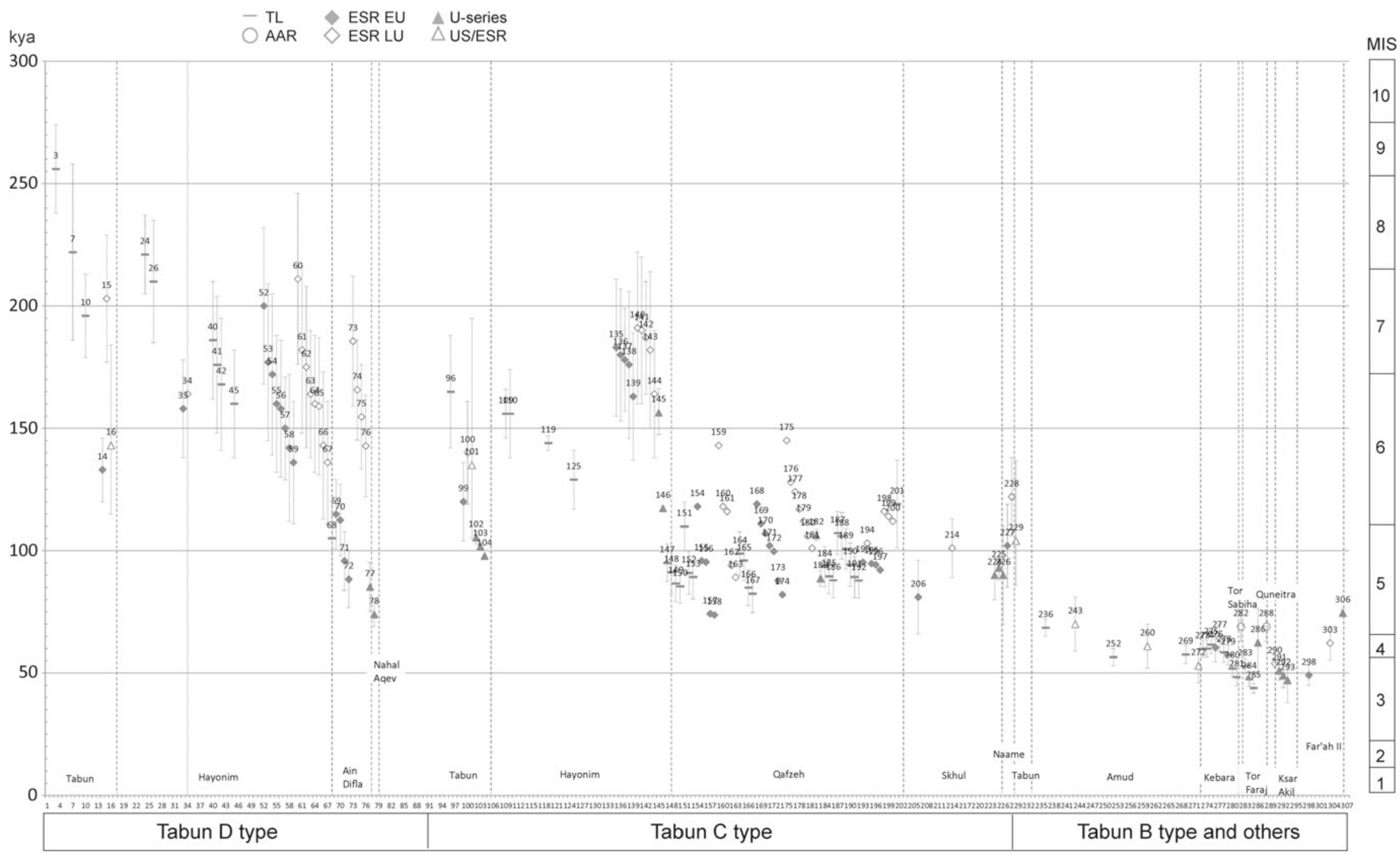


Fig. 4.2 Radiometric dates of Middle Palaeolithic sites in the Levant. Note that the dates are grouped by lithic industries and arranged in the descending order. Numbers in the plots correspond to those in Table 4.2

with *Homo sapiens* during MIS 5. In contrast, almost all of the Afro-Arabian environmental elements are absent in the faunal assemblages at Tabun-B sites, such as Kebara and Amud, where Palearctic-European fauna are dominant as a result of their southward dispersal with Neanderthals during the cold and dry climate of MIS 4 (Tchernov 1998, p. 86; Bar-Yosef 1989). The faunal assemblages from both Hayonim lower and upper E, associated with Tabun D-type and C-type industries respectively, are characterized by the presence of earlier Pleistocene fauna and the predominance of Palearctic mammals, indicating their chronological precedence to Qafzeh. These patterns in bio-cultural chronology generally fit the radiometric dates for Qafzeh, Kebara, Amud, and Hayonim E. The suggested correlation of the fauna from Tabun layer B to MIS 4 does not support the revised ESR dates mentioned above, questioning the validity of the dating results (Grün and Stringer 2000).

4.3.2 Upper Palaeolithic and Early Epipalaeolithic

Despite the presence of key stratigraphic evidence for cultural sequences at some cave and rock-shelter sites, such as at Ksar Akil, much of the archaeological remains of these time periods come from open-air sites particularly in the arid zone, necessitating the use of radiometric dates for the establishment of cultural chronology. For the UP and early Epipalaeolithic, our database includes 200 dates from 82 layers at 47 sites (Table 4.3). Most of them are radiocarbon dates with some TL dates from Jerf Ajla and Umm el-Tlel. Excluding radiocarbon dates on bone or shell as well as clearly anomalous dates, we plot the distribution of 152 dates from cultural layers, and grouped into lithic industries (Fig. 4.3). Some cultural layers, e.g., Umm el-Tlel, Ksar Akil (Tixier's VII), and Wadi Kharar 16R (Nishiaki et al. 2012a), are not classed into any of the industries because their cultural attribution is still under examination or controversial.

The overall pattern observable in this cultural chronological scheme conforms to an earlier suggestion that the IUP or Emiran is followed by the Ahmarian, that precedes the appearance of the Levantine Aurignacian regardless of its various definitions and interpretations, as described above (Belfer-Cohen and Goring-Morris 2003; Gilead 1995; Marks 2003).

The distribution of dates for the Early and Late Ahmarian are continuous, indicating that these two industries occurred sequentially. This is consistent with the idea that the technological shift from the Early to the Late Ahmarian is gradual (Coinman 2003). Such a gradual transition may also apply to the boundary between the Late Ahmarian and the Kebaran. Their temporal ranges indicated by C14 dates appear sequential, and some assemblages, e.g. Ohalo II and Fazael X, are suggested to represent technological transition from the Late Ahmarian to the Kebaran (Nadel 2003). If these observations are valid, the periodical boundary between the UP and Epipalaeolithic in the Levant may be characterized by gradual technological transition rather than sudden shift.

On the other hand, there is considerable overlap in the temporal range between the Early Ahmarian and the IUP, although it is widely recognized that the technological change from IUP to the Early Ahmarian is sequential, as attested by the stratigraphic sequence at Ksar Akil (Ohnuma 1988) and Üçağızlı (Kuhn et al. 2009). The apparent chronological overlap is created by the radiocarbon dates from Kebara Units III and IV (Early Ahmarian; No. 22–29 in Table 4.3) that are dated distinctively earlier than other Ahmarian assemblages as well as by a younger group of dates for IUP assemblages from Üçağızlı, Jerf Ajla, and Umm el-Tlel (No. 9, 10, 12, 13, 17–21 in Table 4.3). It is untenable to suggest, solely based on the distribution of radiometric dates, the contemporaneity between the IUP and the Ahmarian considering the difficulties in obtaining reliable radiocarbon dates close to the methodological limit, as discussed by Kuhn et al. (2009, pp. 90–91), and possible contamination of charcoal samples at Kebara due to complicated depositional processes from the latest Middle Palaeolithic (Unit V) to the early Ahmarian layers (Units III and IV) (Zilhão 2007, p. 11 and the chapter by Zilhão in this volume), as well as large error ranges of TL dates. However, I suggest that the IUP industry may have lasted somewhat later in inland Syria than in the Levant because (1) TL and radiocarbon dates at Umm el-Tlel (No. 20 and 21 in Table 4.3) are consistent with each other and (2) we have so far no Early Ahmarian assemblages comparable to those of Ksar Akil XVI-XVII or Üçağızlı B-C in inland Syria.

In this way, I suggest more or less sequential occurrences of blade dominant industries, including the IUP, the Early and Late Ahmarian, and the Kebaran, that is interpreted by some researchers to constitute a long-term autochthonous lithic tradition (i.e., the Levantine Leptolithic Lineage: Marks 2003). On the other hand, the distribution of available dates for the Levantine Aurignacian sensu lato appears discontinuous. This observation is exemplified by the cluster of dates for the assemblages of the Classic Levantine Aurignacian, such as Kebara Units I-II, Raqefet layer III, and Ksar Akil (Tixier's Phase VI) between ca. 35–30 kya (uncalibrated). Somewhat younger radiocarbon dates measured on bones from Hayonim D and shells from Ksar Akil VIII are not considered here. There is a general contemporaneity with this period based on a cluster of dates from Umm el-Tlel, Ksar Akil (Tixier's Phase VII), and Wadi Kharar 16R (Nishiaki et al. 2012a). Although the cultural attribution of these assemblages is still controversial or under examination, this cluster of dates may indicate

Table 4.3 List of radiometric dates of Upper Palaeolithic and early Epipalaeolithic sites in the Levant

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
1	Boker Tachtit	1	C14	SMU-580	Charcoal	47,280	9,050	9,050	O
2	Boker Tachtit	1	C14	SMU-259	Charcoal	46,930	2,420	2,420	O
3	Boker Tachtit	1	C14	SMU-184	Charcoal	>45,570			
4	Boker Tachtit	1	C14	GY-3642	Charcoal	>34,950			
5	Boker Tachtit	4	C14	SMU-579	Charcoal	35,055	4,100	4,100	O
6	Üçağızlı Magara	H [locus 2: test trench]	C14-AMS	AA-35625	Charcoal	41,400	1,100	1,100	O
7	Üçağızlı Magara	H [locus 2: test trench]	C14-AMS	AA-27994	Charcoal	39,400	1,200	1,200	O
8	Üçağızlı Magara	H [locus 2: test trench]	C14-AMS	AA-27995	Charcoal	38,900	1,100	1,100	O
9	Üçağızlı Magara	H [locus 2: test trench]	C14-AMS	AA-35261	Charcoal	35,670	730	730	O
10	Üçağızlı Magara	H [locus 2: test trench]	C14-AMS	AA-37623	Charcoal	33,040	1,400	1,400	O
11	Üçağızlı Magara	G	C14-AMS	AA-37626	Charcoal	39,100	1,500	1,500	O
12	Üçağızlı Magara	F	C14-AMS	AA-37624	Charcoal	35,020	740	740	O
13	Üçağızlı Magara	F	C14-AMS	AA-35260	Charcoal	34,000	690	690	O
14	Jerf Ajla	Brown 1 (Units A, B, C)	TL	JA-7	Burnt flint	42,600	5,800	5,800	O
15	Jerf Ajla	Brown 1 (Units A, B, C)	TL	JA-2	Burnt flint	40,700	6,400	6,400	O
16	Jerf Ajla	Brown 1 (Units A, B, C)	TL	JA-3	Burnt flint	37,300	4,900	4,900	O
17	Jerf Ajla	Brown 1 (Units A, B, C)	TL	Average	Burnt flint	35,600	3,400	3,400	O
18	Jerf Ajla	Brown 1 (Units A, B, C)	TL	JA-8	Burnt flint	35,500	4,400	4,400	O
19	Jerf Ajla	Brown 1 (Units A, B, C)	TL	JA-1	Burnt flint	31,000	3,400	3,400	O
20	Umm el-Tlel	III2a’	TL	GifA-93215	Burnt flint	36,000	2,500	2,500	O
21	Umm el-Tlel	III2a’	C14-AMS	GifA-93216	Charcoal	34,530	750	750	O
22	Kebara	E (IV)	C14-AMS	Pta-5141	Charcoal	43,700	1,800	1,800	O
23	Kebara	E (IV)	C14-AMS	Pta-5002	Charcoal	42,500	1,800	1,800	O
24	Kebara	E (IV)	C14-AMS	Pta-4987	Charcoal	42,100	2,100	2,100	O
25	Kebara	E (IV)	C14-AMS	OxA-3978	Charcoal	28,890	400	400	
26	Kebara	E (III)	C14-AMS	OxA-3977	Charcoal	43,800			O
27	Kebara	E (III)	C14-AMS	OxA-3976	Charcoal	43,500	2,200	2,200	O
28	Kebara	E (III)	C14-AMS	Gif-TAN-90037	Charcoal	42,500			O
29	Kebara	E (III)	C14-AMS	Gif-TAN90168	Charcoal	41,700			O
30	Kebara	E (III)	C14-AMS	Pta-4267	Charcoal	36,100	1,100	1,100	O
31	Kebara	E (III)	C14-AMS	OxA-1567	Charcoal	35,600	1,600	1,600	O
32	Abu Noshra II		C14	SMU-2372	Charcoal	48,250	2,810	2,810	
33	Abu Noshra II		C14	SMU-2122	Charcoal	38,924	1,529	1,529	O
34	Abu Noshra II		C14	ETH-3076	Charcoal	33,940	790	790	O
35	Abu Noshra II		C14	ETH-3075	Charcoal	33,470	680	680	O
36	Abu Noshra II		C14	SMU-1762	Charcoal	31,585	2,275	2,275	O
37	Abu Noshra II		C14	SMU-1772	Charcoal	31,023	8,537	8,537	O
38	Abu Noshra VI		C14	SMU-2371	Charcoal	31,100	300	300	O
39	Abu Noshra I		C14	SMU-2254	Charcoal	35,824	1,090	1,090	O
40	Abu Noshra I		C14	SMU-2007	Charcoal	35,805	1,520	1,520	O
41	Abu Noshra I		C14	SMU-1824	Charcoal	31,330	2,880	2,880	O
42	Abu Noshra I		C14	B-12125	Charcoal	>30,440			

(continued)

Table 4.3 (continued)

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
43	Abu Noshra I		C14	B-13898	Charcoal	29,580	1,610	1,340	O
44	Abu Noshra I		C14	B-13897	Charcoal	25,950	360	360	O
45	Boker A	I	C14	SMU-578	Charcoal	37,920	2,810	2,810	O
46	Boker A	I	C14	SMU-187	Charcoal	>33,600			
47	Boker A	I	C14	SMU-260	Charcoal	>33,420			
48	Qseimeh I		C14	DRI-2965	Ostrich eggshell	34,010	510	510	
49	Qadesh Barnea 501		C14	Pta-2819	Ostrich eggshell	33,800	940	940	
50	Qadesh Barnea 601B		C14	Pta-2964	Ostrich eggshell	32,470	780	780	
51	Lagama VIII		C14	SMU-119	Ostrich eggshell	32,980	2,140	2,140	
52	Lagama VII		C14	SMU-172	Charcoal	34,170	3,670	3,670	O
53	Lagama VII		C14	SMU-185	Charcoal	31,210	2,780	2,780	O
54	Lagama VII		C14	RT-413A	Charcoal	>19,900			
55	Üçağızlı Magara	C [locus 1]	C14-AMS	Gif-8766	Marine shell	32,250	800	800	
56	Üçağızlı Magara	B1	C14-AMS	AA38201	Marine shell	32,670	760	760	
57	Üçağızlı Magara	B	C14-AMS	AA38203	Marine shell	29,130	380	380	
58	Qafzeh Cave	11	C14-AMS	GifA-97338	Charcoal	31,520	490	490	O
59	Qafzeh Cave	11	C14-AMS	AA-27290	Charcoal	29,320	360	360	O
60	Qafzeh Cave	9	C14-AMS	GifA-97337	Charcoal	28,340	360	360	O
61	Qafzeh Cave	9	C14-AMS	AA-27291	Charcoal	28,020	320	320	O
62	Qafzeh Cave	9	C14-AMS	GifA-98230	Charcoal	29,060	390	390	O
63	Qafzeh Cave	9	C14-AMS	AA-27292	Charcoal	28,380	330	330	O
64	Qafzeh Cave	8	C14-AMS	GifA-98229	Charcoal	27,510	340	340	O
65	Qafzeh Cave	8	C14-AMS	AA-27294	Charcoal	27,080	270	270	O
66	Qafzeh Cave	8	C14-AMS	GifA-97336	Charcoal	26,720	300	300	O
67	Qafzeh Cave	8	C14-AMS	AA-27289	Charcoal	27,000	280	280	O
68	Qafzeh Cave	8	C14-AMS	Gif-98231	Charcoal	28,460	360	360	O
69	Qafzeh Cave	8	C14-AMS	AA-27293	Charcoal	26,540	280	280	O
70	Qafzeh Cave	D (8–9)	C14	asparatic acid	Bone	46,950			
71	Qafzeh Cave	D (8–9)	C14	asparatic acid	Bone	38,950			
72	Qafzeh Cave	D (8–9)	C14	asparatic acid	Bone	31,950			
73	Boker BE	III	C14	SMU-188 (Level III)	Charcoal	27,450	1,300	1,300	O
74	Boker BE	III	C14	SMU-229 (Level III)	Charcoal	26,660	500	500	O
75	Boker BE	III	C14	SMU-228 (Level III)	Charcoal	26,030	600	600	O
76	Boker BE	II	C14	SMU-227	Charcoal	26,950	520	520	O
77	Boker BE	II	C14	SMU-565	Charcoal	24,630	390	390	O
78	A306A		C14	Pta-2950	Ostrich eggshell	27,100	410	410	
79	Thalab al-Buhayla	E	C14-AMS	Beta-129817	Charcoal	24,900	130	130	O
80	Thalab al-Buhayla	C	C14-AMS	Beta-129818	Charcoal	25,680	100	100	O
81	Lagama IIID		C14	SMU-118	Ostrich eggshell	30,050	1,240	1,240	
82	Ksar Akil	Tixier’s III	C14-AMS	OxA-1798	Charcoal	29,300	800	800	O
83	Ksar Akil	Tixier’s III	C14-AMS	OxA-1797	Charcoal	26,900	600	600	O
84	Ksar Akil	Tixier’s III	C14	MC-1191	Charcoal	26,500	900	900	O

(continued)

Table 4.3 (continued)

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
85	Ksar Akil	Tixier's III	C14-AMS	OxA-1796	Charcoal	21,100	500	500	O
86	Ain al-Buhayra	Unit F	C14-AMS	Beta-55928	Charcoal	25,950	440	440	O
87	Ain al-Buhayra	Units H-I	C14-AMS	Beta-55931	Charcoal	23,560	250	250	O
88	Ain al-Buhayra	Units H-I	C14-AMS	Beta-56424	Charcoal	23,500	270	270	O
89	Ain al-Buhayra	Units H-I	C14-AMS	Beta-118757	Charcoal	20,670	600	600	O
90	Ain al-Buhayra	Units H-I	C14-AMS	UA-4395	Charcoal	20,300	600	600	O
91	Yutil al-Hasa	Area A	C14-AMS	Beta-129813	Charcoal	22,790	80	80	O
92	Yutil al-Hasa	Area A	C14-AMS	UA-4396	Charcoal	19,000	1,300	1,300	O
93	Shunera XVI		C14	RT-1084N	Carbonate	22,200	400	400	
94	Shunera XVI		C14	RT-1072N	Ostrich eggshell	16,200	170	170	
95	Shunera XVI		C14	Pta-3703	Ostrich eggshell	16,100	150	150	
96	Shunera XVI		C14	Pta-3702	Ostrich eggshell	15,800	160	160	
97	Shunera XVI		C14	RT-1069	Charcoal	102	2	2	
98	Meged		C14-AMS	AA-26552	Charcoal	20,485	155	155	O
99	Meged		C14-AMS	AA-26551	Charcoal	18,840	140	140	O
100	Ohalo II		C14-AMS	RT-1625	Charcoal	21,050	330	330	O
101	Ohalo II		C14-AMS	RT-1624	Charcoal	20,840	290	290	O
102	Ohalo II		C14-AMS	RT-1620	Fraxinus s.	20,830	180	180	O
103	Ohalo II		C14-AMS	RT-1622	Pistacia a.	20,190	170	170	O
104	Ohalo II		C14-AMS	Pta-5387	Charcoal	20,100	440	440	O
105	Ohalo II		C14-AMS	RT-1621	Rhamnus	20,070	270	270	O
106	Ohalo II		C14-AMS	RT-1619	Tamarix	19,860	190	190	O
107	Ohalo II		C14-AMS	RT-1248	Charcoal	19,800	360	360	O
108	Ohalo II		C14-AMS	Pta-5386	Charcoal	19,600	400	400	O
109	Ohalo II		C14-AMS	RT-1616	Pistacia a.	19,590	150	150	O
110	Ohalo II		C14-AMS	RT-1342	Charcoal	19,500	170	170	O
111	Ohalo II		C14-AMS	Pta-5374	Charcoal	19,400	220	220	O
112	Ohalo II		C14-AMS	OxA-2565	Hordeum	19,310	190	190	O
113	Ohalo II		C14-AMS	RT-1250	Tamarix	19,250	460	460	O
114	Ohalo II		C14-AMS	RT-1618	Tamarix	19,220	180	180	O
115	Ohalo II		C14-AMS	OxA-2566	Hordeum	19,110	390	390	O
116	Ohalo II		C14-AMS	RT-1251	Charcoal	19,000	190	190	O
117	Ohalo II		C14-AMS	RT-1252	Tamarix	18,900	400	400	O
118	Ohalo II		C14-AMS	RT-1358	Charcoal	18,760	180	180	O
119	Ohalo II		C14-AMS	RT-1617	Populus e.	18,700	180	180	O
120	Ohalo II		C14-AMS	OxA-2564	Hordeum	18,680	180	180	O
121	Ohalo II		C14-AMS	RT-1343	Charcoal	18,600	220	220	O
122	Ohalo II		C14-AMS	RT-1244	Charcoal	18,360	230	230	O
123	Ohalo II		C14-AMS	RT-1623	Tamarix	18,210	240	240	O
124	Ohalo II		C14-AMS	RT-1297	Charcoal	17,500	200	200	O
125	Azariq XIII		C14-AMS	RT-1105	Carbonate	19,700	400	400	
126	Azariq XIII		C14-AMS	OxA-2142	Charcoal	15,160	190	190	
127	Azariq XIII		C14-AMS	RT-1081	Charcoal	10,700	230	230	
128	Fazael X		C14-AMS	OxA-2870	Charcoal	15,450	130	130	
129	Azraq 17 (trench 2)		C14-AMS	OxA-869	Charcoal	13,260	200	200	
130	Meged		C14-AMS	AA-22314	Charcoal	18,125	135	135	O
131	Meged		C14-AMS	AA-22313	Charcoal	18,065	120	120	O
132	Ain Qasiyya	Area A Unit IIIa	C14-AMS	Poz-33101	Charcoal	19,690	150	150	

(continued)

Table 4.3 (continued)

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
133	Ain Qasiyya	Area A Unit IIIa	C14-AMS	OxA-1883	Charcoal	17,555	75	75	O
134	Ain Qasiyya	Area A Unit IIIa	C14-AMS	OxA-18832	Charcoal	17,495	70	70	O
135	Ain Qasiyya	Area B Unit IIIa	C14-AMS	Poz-33103	Charcoal	16,960	110	110	O
136	Kharaneh IV	Area B	C14-AMS	OxA-22273	Charcoal	15,890	90	90	O
137	Kharaneh IV	Area B	C14-AMS	OxA-22274	Charcoal	15,770	80	80	O
138	Ein Gev I		C14	GrN-5576	Burnt bone	15,700	415	415	
139	Urkan II		C14-AMS	OxA-2841	Charcoal	15,730	130	130	O
140	Urkan II		C14-AMS	OxA-2835	Charcoal	15,190	130	130	O
141	Urkan II		C14-AMS	OxA-2838	Charcoal	15,050	160	160	O
142	Urkan II		C14-AMS	OxA-2842	Charcoal	14,980	200	200	O
143	Urkan II		C14-AMS	OxA-2840	Charcoal	14,880	120	120	O
144	Urkan II		C14-AMS	OxA-2836	Charcoal	14,860	130	130	O
145	Urkan II		C14-AMS	OxA-2839	Charcoal	14,800	130	130	O
146	Urkan II		C14-AMS	OxA-2837	Charcoal	14,650	120	120	O
147	Urkan II		C14-AMS	OxA-1503	Charcoal	14,440	150	150	O
148	Umm el-Tlel	V (= II 1) Ahmarian	C14-AMS	Gif-90034	Charcoal	30,310	670	670	O
149	Umm el-Tlel	II 2a Ahmarian	TL		Burnt flint	34,000	2,500	2,500	O
150	Umm el-Tlel	II 2b Aurignacian	C14-AMS	Gif A-93212	Charcoal	32,000	580	580	O
151	Umm el-Tlel	XII (= II 4?) unknown	C14-AMS	Gif-90040	Charcoal	30,790	760	760	O
152	Ksar Akil	Tixier's VII	C14	MC-1192	Charcoal	32,000	1,500	1,500	O
153	Kharar 16R	Area 2	C14-AMS	IAAA-103837	Charcoal	33,130	160	160	O
154	Kebara	D (II)	C14-AMS	Gx-17276	Charcoal	42,800	4,800	4,800	
155	Kebara	D (II)	C14-AMS	OxA-1230	Charcoal	36,000	1,600	1,600	O
156	Kebara	D (II)	C14-AMS	Gif-TAN-90028	Charcoal	34,300	1,100	1,100	O
157	Kebara	D (II)	C14-AMS	OxA-3975	Charcoal	33,920	690	690	O
158	Kebara	D (II)	C14-AMS	Gif-TAN-90151	Charcoal	32,670	800	800	O
159	Kebara	D (II)	C14-AMS	Pta-4263	Charcoal	31,400	480	480	O
160	Kebara	D (II)	C14-AMS	Pta-4269	Charcoal	28,700	450	450	
161	Kebara	D (I)	C14-AMS	OxA-3974	Charcoal	34,510	740	740	O
162	Kebara	D (I)	C14-AMS	Pta-4268	Charcoal	32,200	630	630	O
163	Kebara	D (I)	C14-AMS	Pta-4247	Charcoal	22,900	250	250	
164	Raqefet	III	C14-AMS	RTT4945	Charcoal	30,540	440	440	O
165	Hayonim	Layer D	C14-AMS	OxA-2805	Bone	29,980	720	720	
166	Hayonim	Layer D	C14-AMS	OxA-2801	Bone	28,900	650	650	
167	Hayonim	Layer D	C14-AMS	OxA-2802	Bone	27,200	600	600	
168	Ksar Akil	Tixier's VI	C14-AMS	OxA-1805	Charcoal	32,400	1,100	1,100	O
169	Ksar Akil	Tixier's VI	C14-AMS	OxA-1804	Charcoal	31,200	1,300	1,300	O
170	Ksar Akil	VIII	C14	GrN-2195	Shell	28,840	380	380	
171	Ksar Akil	VIII	C14	MC-686-688	Shell	27,000			
172	Ksar Akil	VIII	C14	MC-680-684	Shell	26,000			
173	Qseimeh II		C14	DRI-2966	Ostrich eggshell	30,500	330	330	
174	Boker BE	I	C14	SMU-186	Charcoal	25,610	640	640	O
175	Boker BE	I	C14	SMU-566	Charcoal	25,250	345	345	O
176	Ein Aqev	12	C14	SMU-5	Charcoal	19,980	1,200	1,200	O
177	Ein Aqev	11	C14	SMU-8	Charcoal	17,390	560	560	O
178	Ein Aqev	9	C14	SMU-6	Charcoal	17,890	600	600	O
179	Ein Aqev	7	C14	I-5495	Charcoal	17,510	560	560	O
180	Ein Aqev	5	C14	I-5494	Charcoal	16,900	250	250	O
181	Madamagh	D	C14	KN-3594	Bone	15,300	600	600	

(continued)

Table 4.3 (continued)

No. in the plot	Site name	Layer	Dating method	Laboratory No.	Samples	Date (mean)	SD (positive)	SD (negative)	Selected dates
182	Ksar Akil	Tixier's IV	C14-AMS	OxA-1803	Charcoal	30,250	850	850	O
183	Fazael IX		C14-AMS	OxA-2871	Charcoal	17,660	160	160	O
184	Tor Sageer		C14-AMS	Beta-129810	Charcoal	22,590	80	80	O
185	Tor Sageer		C14-AMS	Beta-129811	Charcoal	20,840	340	340	O
186	Tor Sageer		C14-AMS	Beta-129809	Charcoal	20,330	60	60	O
187	Gaiyfa X		C14	DRI-3001	Charcoal	19,525	199	199	O
188	Wadi Hammeh 26		C14-AMS	SUA-2101	Charcoal	19,500	600	600	O
189	Uwaynid 18	Upper	C14-AMS	OxA-864	Charcoal	19,800	350	350	O
190	Uwaynid 18	Upper	C14-AMS	OxA-868	Charcoal	19,500	250	250	O
191	Uwaynid 14	Upper	C14-AMS	OxA-865	Charcoal	18,900	250	250	O
192	Uwaynid 14	Middle	C14-AMS	OxA-866	Charcoal	18,400	250	250	O
193	Tor Tareeq	Lower	C14-AMS	UA-4391	Charcoal	16,900	500	500	O
194	Tor Tareeq	Lower	C14-AMS	UA-4392	Charcoal	15,580	250	250	O
195	Ain Qasiyya	Area D Unit IIIa	C14-AMS	Poz-33106	Charcoal	16,080	100	100	O
196	Madamagh	A	C14	KN-3593	Bone	14,300	650	650	
197	Jilat 6	Phase C	C14-AMS	OxA-539	Charcoal	7,980	150	150	
198	Jilat 6	Phase B	C14-AMS	OxA-522	Charcoal	11,740	80	80	
199	Jilat 6	Phase B	C14-AMS	OxA-523	Charcoal	11,450	200	200	
200	Uwaynid 18	Lower	C14-AMS	OxA-867	Charcoal	23,200	400	400	

the timing of technological diversification between ca. 35–30 kya (uncalibrated).

The number of dates obtained for the Arqov/Divshon and the Atlitian assemblages are limited, but currently available dates are later than the Classic Levantine Aurignacian by thousands of years or more than ten thousand years, except for a single early date for Ksar Akil (Tixier's IV). This chronological gap between the Classic Levantine Aurignacian and other flake-based industries (i.e., the Arqov/Divshon and the Atlitian) is consistent with the position that these three industries should be separate entities rather than lumping them as the Levantine Aurignacian sensu lato (Goring-Morris and Belfer-Cohen 2006). It is notable that the temporal ranges of the Arqov/Divshon and Atlitian significantly overlap that of the Nebekian, that is conventionally included in the Epipalaeolithic period. This chronological overlap between ca. 22 and 17 kya (uncalibrated) may represent another phase of technological diversification at the transition from the latest UP to the early Epipalaeolithic period.

In sum, the above chronological examination allowed us to detect a sequential occurrence of blade dominant industries from the IUP through the Ahmarian to the Kebaran that may represent a long-term technological tradition. On the other hand, discontinuous clusters of dates for other industries may indicate a period of increased cultural variability. However, the apparent chronological overlap in the distribution of radiocarbon dating plots may only be a product of error ranges. To obtain further insights, we examine geographical distributions of lithic industries below.

4.4 Geographical Examination of the Middle and Upper Palaeolithic Industries

4.4.1 Middle Palaeolithic

Figures 4.4, 4.5, and 4.6 show the distribution of sites where Tabun D-, C-, and B-type assemblages were recovered. The sites with Tabun D-type assemblages are distributed widely in the Levant from the south at Rosh Ein Mor and Nahal Aqev in the Negev to the north at Dereriyeh Cave in the Afrin basin (Nishiaki et al. 2011). They are also distributed in the coastal as well as inland areas. In contrast, the Tabun C-type assemblages are mainly distributed from the central to the northern Levant, and no Tabun C-assemblages have been recovered in the southern Levant. While explaining this geographic pattern is beyond the scope of this paper, the technological attribution of the Quneitra assemblage to the Tabun C-type is consistent with its geographical proximity to other Tabun C-type sites (Fig. 4.5). In addition, the lack of Tabun C-type sites in the southern Levant cannot be taken as a support for the persistence of some Tabun D-type sites in the southern Levant (e.g., Nahal Aqev and 'Ain Difla) and their contemporaneity with the Tabun C-assemblages in north unless the dates proposed for Nahal Aqev and 'Ain Difla are validated.

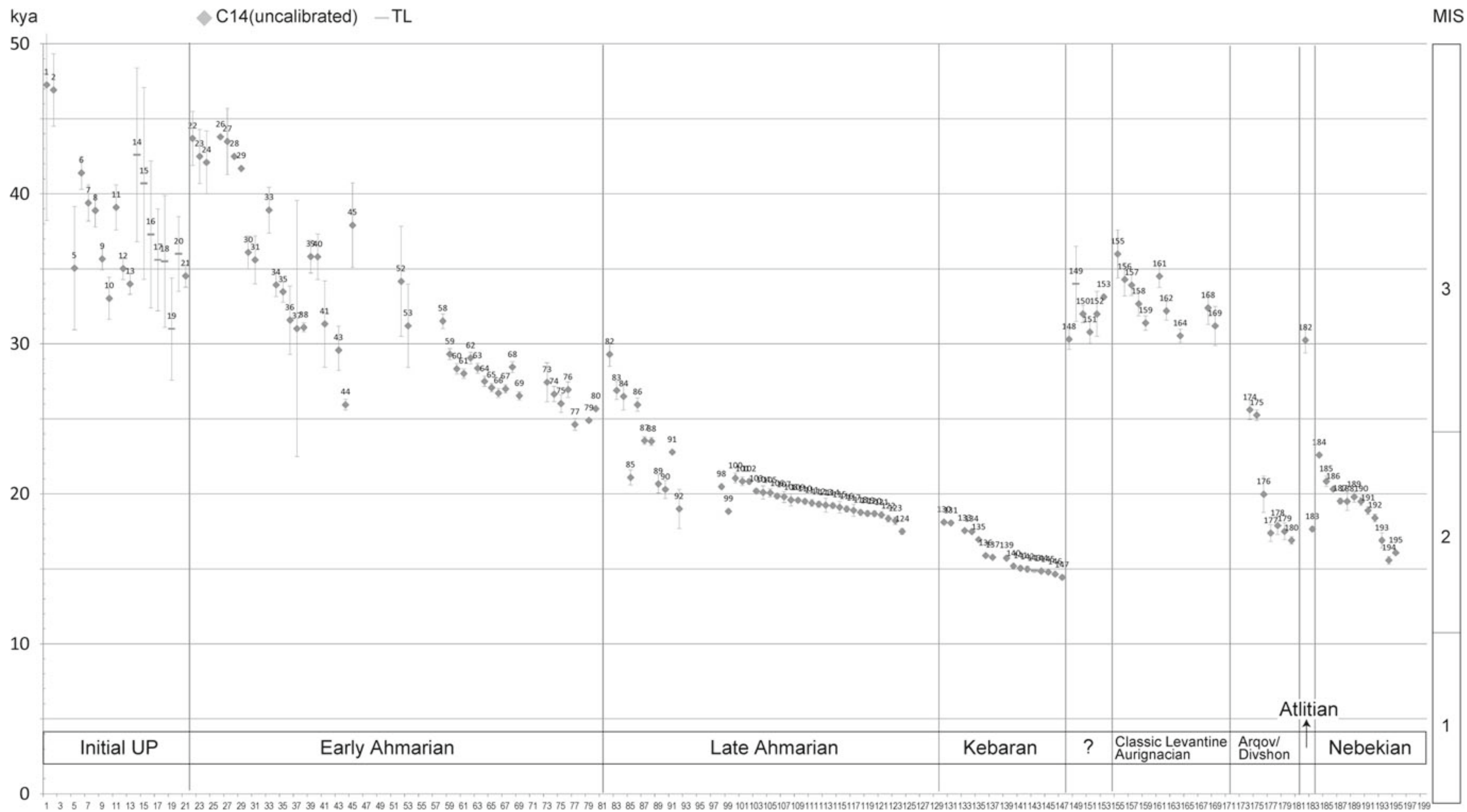


Fig. 4.3 Radiometric dates of Upper Palaeolithic and early Epipalaeolithic sites in the Levant. Note that the dates are grouped by lithic industries and arranged in the descending order. Numbers in the plots correspond to those in Table 4.3

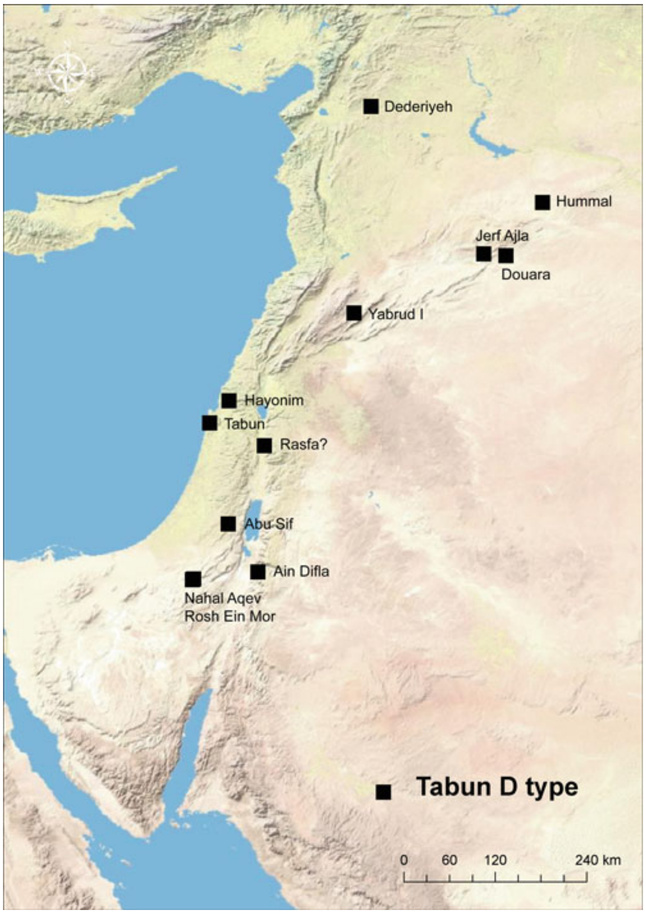


Fig. 4.4 Geographic distributions of the Tabun D-type assemblages in the Levant

Fig. 4.5 Geographic distributions of the Tabun C-type assemblages in the Levant

The Tabun B-type assemblages are distributed widely from the north at Dederiyeh Cave (Nishiaki et al. 2011) to south at Tor Faraj (Henry 2004), but their distribution in the inland zone is not well attested, as the assemblages there are distinguished from the Tabun B-type industry on techno-typological grounds and named the Late Mousterian, that may represent a regional cultural variation.

4.4.2 Upper Palaeolithic

The IUP sites are widely distributed in the Levant from Üçağızlı (Kuhn et al. 2009) in the north to Wadi Aghar (Henry 1995) in the south as well as from coastal areas through to the inland zones (Fig. 4.7). Although such a wide geographic range of the IUP is comparable to (or even greater than) that of the preceding Tabun B-type industry, the former is characterized by clearer regional patterns, that are observable in the occurrence of some tool types. For example, the IUP assemblages in the northern Levant are characterized by chamfered pieces along the coastal areas, such as at Ksar Akil and Üçağızlı (Ohnuma 1988; Kuhn et al. 2009), and by Umm el Tlel points in the inland areas (Bar-Yosef 2000). To their south in the central to southern Levant, the IUP assemblages are characterized by Emireh points (e.g., Marks 1983; Copeland 2000).

The distribution of the Early Ahmarian sites is also broad in the Levant, significantly overlapping the range of the preceding IUP industry (Fig. 4.8). This is consistent with some researchers' understanding that the Early Ahmarian appeared as a local technological change from the IUP. However, I argue that this technological change was not uniform in the Levant. This is because the assemblages that are currently grouped under the label of "the Ahmarian" encompass regional variability, for example, in the form and frequency of pointed tools and the dimension of blade products. While Ksar Akil points and *pointes a fáce plane* made on relatively large blades characterize the northern coastal areas (Bergman 1981; Kuhn et al. 2009), backed or pointed bladelets occur frequently in the southern Levant (Bar-Yosef and Phillips 1977; Marks and

Fig. 4.6 Geographic distributions of the Tabun B-type assemblages in the Levant

Fig. 4.7 Geographic distributions of the Initial Upper Palaeolithic assemblages in the Levant

Kaufman 1983; Coinman 2003). In the Sinai Peninsula, no IUP assemblages have been recovered despite clear evidence for the Early Ahmarian industry in this region (Bar-Yosef and Phillips 1977; Phillips 1988), indicating either a lack of human occupation prior to the Early Ahmarian or the lack of discovery of such archeological remains. In contrast, despite the presence of the IUP in the northern inland zone, particularly at Umm el Tlel in the el-Kowm basin, no Early Ahmarian assemblages comparable to those from Ksar Akil XVI-XVII or Üçağızlı B-C have been recovered there. Instead, in the northern inland zone, there are bladelet dominant assemblages at Umm el Tlel (Ploux and Soriano 2003) and Wadi Kharar 16R (Nishiaki et al. 2012a), whose radiocarbon dates around 33–30 ka (uncalibrated) (No. 148, 150, 151, and 153 in Table 4.3) follow those of IUP assemblages at Umm el-Tlel (No. 20–21 in Table 4.3).

Cultural regionality during the period of the Early Ahmarian is also evident in the geographic distribution of the Classic Levantine Aurignacian industry (Fig. 4.9), whose techno-typological difference from the Early Ahmarian is widely recognized among researchers (e.g., Goring-Morris and Belfer-Cohen 2006; Marks 2003). In contrast to the broad distribution of the Early Ahmarian assemblages, that of the Classic Levantine Aurignacian is restricted in the central Levant. Two sites, located east of the coastal mountain ranges, are Yabrud Rockshelter II and el-Quseir. The coastal areas may be the central zone of the Classic Levantine Aurignacian industry given that the cultural attribution of the Yabrud II assemblages varies among researchers (compare Gilead 1991, p. 128 with Goring-Morris and Belfer-Cohen 2006, p. 311).

Although the Late Ahmarian assemblages are widely distributed in the Levant (Fig. 4.10), they are not found in the northern coastal and inland areas or southern Jordan and the Sinai, where the Early Ahmarian assemblages have been recovered. This difference in geographic extent between the Early and Late Ahmarian indicates a chrono-cultural gap after the Early Ahmarian in the areas without the Late Ahmarian sites. Unless this is merely caused by the lack of discovery or recognition of the Late Ahmarian assemblages, I suggest that the technological change from the Early Ahmarian involved regional variations

Fig. 4.8 Geographic distributions of the early Ahmarian assemblages in the Levant

Fig. 4.9 Geographic distributions of the Classic Levantine Aurignacian assemblages in the Levant

that researchers have not yet clarified. At present, it is notable that the narrow distribution of the Late Ahmarian is similar to that of the following Kebaran industry. This is consistent with the chronological and technological observations that the Kebaran emerged from the Late Ahmarian.

Despite the reduced range of the Late Ahmarian, in comparison to the Early Ahmarian, it is still wider than the extent of the Arqov/Divshon, the Atlitian, and the Nebekian (Fig. 4.11), that are partly contemporary with the Late Ahmarian or the Kebaran, according to their radiocarbon dates. For example, the Arqov/Divshon assemblages are mainly located in the Negev, and the Atlitian assemblages are currently known only from the central coast and the Jordan Valley. On the other hand, the Nebekian assemblages are mostly distributed in the inland areas to the east of the Jordan Valley, partly occupying the areas beyond the range of the Late Ahmarian. The geographic distributions of these three industries are, thus, restricted and distinct from each other. Such regionally specific distributions are consistent with the possibility of their contemporaneity suggested by their chronological overlaps in the distribution of radiocarbon dates (Fig. 4.3).

4.5 Discussions

4.5.1 Chronological and Geographical Patterns of Lithic Industries

This section summarizes the observations obtained from the above examinations on the chronological and geographical patterns of the MP and UP lithic industries in the Levant. As for the MP, currently available radiometric dates and stratigraphic occurrences of the three MP industries (i.e., Tabun D-, C-, and B-types) indicate that they occurred sequentially. The lack of the Tabun C-type assemblages in the southern Levant, where young radiometric dates have been reported for two Tabun D-type sites (i.e., Nahal Aqev and Ain Difla), cannot be taken as evidence for the temporal overlap between the Tabun D-type and C-type industries because these radiometric dates are either with wide error ranges or without a reliable link to the lithic assemblages as discussed earlier. Other radiometric dates that indicate the chronological overlap between different MP industries are anomalous and can-

Fig. 4.10 Geographic distributions of the Late Ahmarian and Kebaran assemblages in the Levant

not be accepted without further support (i.e., ESR dates for Hayonim Upper E and revised ESR dates for the Tabun Layer B). In fact, the possibility of these overlaps does not gain support from the geographic patterns.

During the UP and early Epipalaeolithic periods, there are generally two patterns in the chronological and geographic distributions of the lithic industries. The first consists of the IUP, the Early and Late Ahmarian, and the Kebaran. Their chronological ranges are sequential, and the geographic distributions are broad with significant overlap existing among the industries, although the range may have been somewhat reduced at the transition point from the Early to the Late Ahmarian. These patterns, as defined by the sequential occurrence and the wide overlapping geographic distribution, appear in accord with some researchers' understanding that these blade dominant industries represent the local lithic tradition (Marks 2003; Belfer-Cohen and Goring-Morris 2007, pp. 200–201).

The second pattern, involving the Classic Levantine Aurignacian, the Arqov/Divshon, the Atlitian, and the Nebekian, is characterized by the appearance of industries in restricted time and space. The chronological ranges are either discontinuous or significantly overlapping, and in the latter case, multiple industries may have co-existed because they tend to be clustered in different regions. Researchers

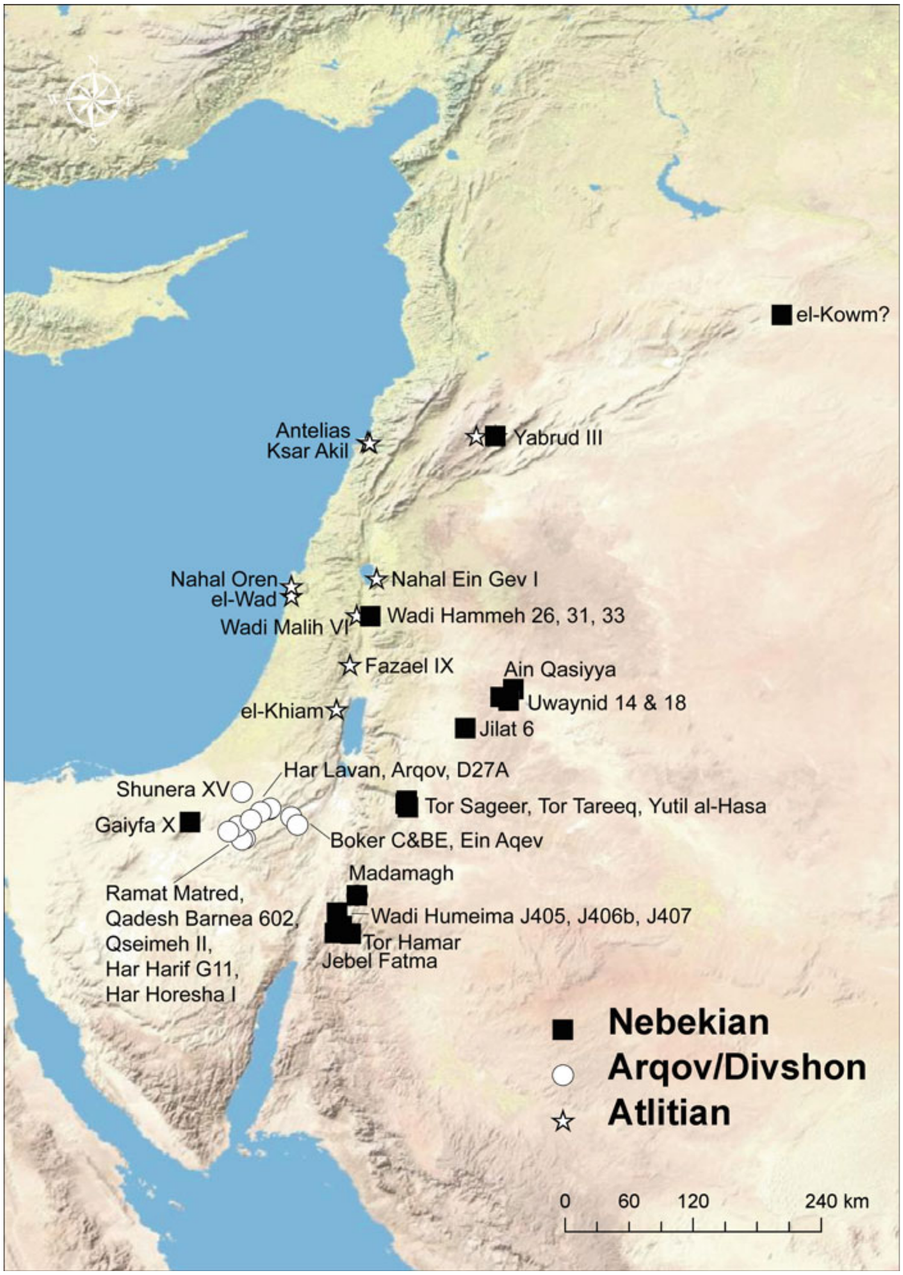


Fig. 4.11 Geographic distributions of the Nebekian, the Arqov/Divshon, and the Atlitian assemblages in the Levant

consider these industries to be technologically different from the local blade industries that show the first pattern although it is difficult with available data to determine whether the second cultural pattern resulted from technological innovations/adaptations by local populations, an influx of ideas/traits from migrating populations, or a change of local cultures under the influence of different cultural groups.

4.5.2 Fossil Evidence in Relation to the MP and UP Industries

4.5.2.1 Middle Palaeolithic

One of the objectives of this paper is to discuss the plausibleness of interpreting the chronological and geographic patterns of lithic industries as they related to the learning behaviors of Neanderthals and *Homo sapiens*. For this purpose, the following briefly reviews current records on human fossils from the MP and UP periods in the Levant (Table 4.1). First, the Neanderthal occupation in the Levant is attested to by the fossil evidence from Kebara, Amud, Tabun, Dederiyeh, and Shukhba (Akazawa and Muhesen 2002; Bar-Yosef and Meignen 2007; Garrod and Bate 1937; Hovers et al. 1995; Shea 2003; Suzuki and Takai 1970). The contexts of Neanderthal fossils are mostly dated to the late Middle Palaeolithic between ca. 45 and 75 kya during MIS 4 on the basis of radiometric dates, stratigraphic positions, and/or faunal spectra. This time period corresponds to the chronological range of the Tabun B-type assemblages, that are in fact associated with Neanderthal fossils found in the above sites.

Early *Homo sapiens* remains recovered in the Middle Palaeolithic strata of Qafzeh and Skhul correspond to MIS 5, having been dated by a series of radiometric dates (ca. 75–130 kya) corroborated by faunal species representation. Lithic assemblages associated with these early *Homo sapiens* are the Tabun C-type. Human teeth associated with the Tabun C-type assemblages at Ras el-Kelb were once suggested to be similar to those from Qafzeh and Skhul. However, a recent reanalysis concludes that the specimens are unidentifiable (Bourke 1997). In addition, there is currently no evidence for the existence of *Homo sapiens* between 45 and 75 kya in west Asia.

Although the above records indicate the association of Neandertals with the Tabun B-type industry and that of *Homo sapiens* with the Tabun C-type, the interpretation of some fossil finds is controversial. For example, the Tabun C1 skeleton, associated with the Tabun C-type assemblage, is broadly recognized as possessing anatomical characteristics representative of Neanderthals (Smith 1995, p. 62; Rak 1998), but some researchers, including the excavators, consider (on the basis of field observations) that the bones may have shifted downward from layer B (Garrod and Bate 1937, p. 64; Bar-Yosef and Callander 1999). This view is supported by a recent analysis of U/Th ratios (Grün and Stringer 2000). This means that the skeleton was originally associated with the Tabun B-type assemblage, that is consistent with other Neanderthal fossils in the Levant, such as Amud and Dederiyeh.

Another controversial specimen is the Tabun C2 fossil. Its stratigraphic association with Layer C (and the Tabun C-type lithic assemblage) is unequivocal, but its biological affinity has been controversial, representing both Neanderthal and *Homo sapiens* attributes (Quam and Smith 1998). If the Neanderthal affinity is accepted, the TL and ESR dates of Tabun layer C (120–180 kya) suggest that Neanderthals appeared in the Levant before *Homo sapiens* at Qafzeh and Skhul and produced the Tabun C-type assemblage. If we accept the attribution of the fossil to *Homo sapiens*, its chrono-cultural association is more consistent with the cases at Qafzeh and Skhul. Alternatively, the controversial anatomical features of the Tabun C2 showing characteristics of both Neanderthal and *Homo sapiens* could imply problems underlying the dichotomous classification of late Middle to Late Pleistocene hominins in this region into "Neanderthal" or "*Homo sapiens*."

Additionally, no identifiable human fossils have been discovered in association with the Tabun D-type industry.

4.5.2.2 Upper and Early Epipalaeolithic

All the identifiable human fossils that have been recovered from these time periods are reported to be *Homo sapiens* (Gilead 1995, p. 136; Smith 1995, p. 64). As listed in Table 4.1, the UP and early Epipalaeolithic industries associated with *Homo sapiens* include the Early and Late Ahmarian, the Classic Levantine Aurignacian, the Atlitian, and the Kebaran. Given this pattern, it would be reasonable to expect that the other industries, such as the Arqov/Divshon and the Nebekian, are also the products of *Homo sapiens*.

The hominin species associated with the IUP has been a significant issue since the Tabun B-type industry, immediately preceding it, is associated with Neanderthals, and the following one, the Early Ahmarian, is associated with *Homo sapiens* (Bergman and Stringer 1989). A report of human teeth recovered in association with the IUP and Early Ahmarian assemblages at Üçağızlı describes that their morphology is "consistent with an attribution to *Homo sapiens*, but at least one possesses features more commonly associated with Neandertals" (Kuhn et al. 2009, p. 108). In addition, recent re-examinations of a partial maxilla ("Ethelruda") from Ksar Akil XXV suggested that it may represent an anatomically modern human (Douka et al. 2013 and references therein) although more complete specimens or detailed analyses are necessary in future to clarify the taxonomic status of the makers of the IUP industry.

4.5.3 On the Approach to Learning Strategies of Neanderthals and *Homo sapiens* from Lithic Industry Records

On the basis of the current fossil evidence, as reviewed above, this section discusses how insights into learning behaviors by Neanderthals and *Homo sapiens* can be obtained from the chronological and geographical patterns of the MP and UP lithic industries. The discussion will focus on the issues related to the attempt to use lithic industry records to measure the rate and cumulativeness of cultural changes as these aspects are considered key variables in the evolutionary model of learning behaviors (Borenstein et al. 2008).

4.5.3.1 Duration of the Lithic Industry: A Rate of Culture Change?

One of the methods for assessing the speed of culture change is to compare the duration of lithic industries. In fact, the

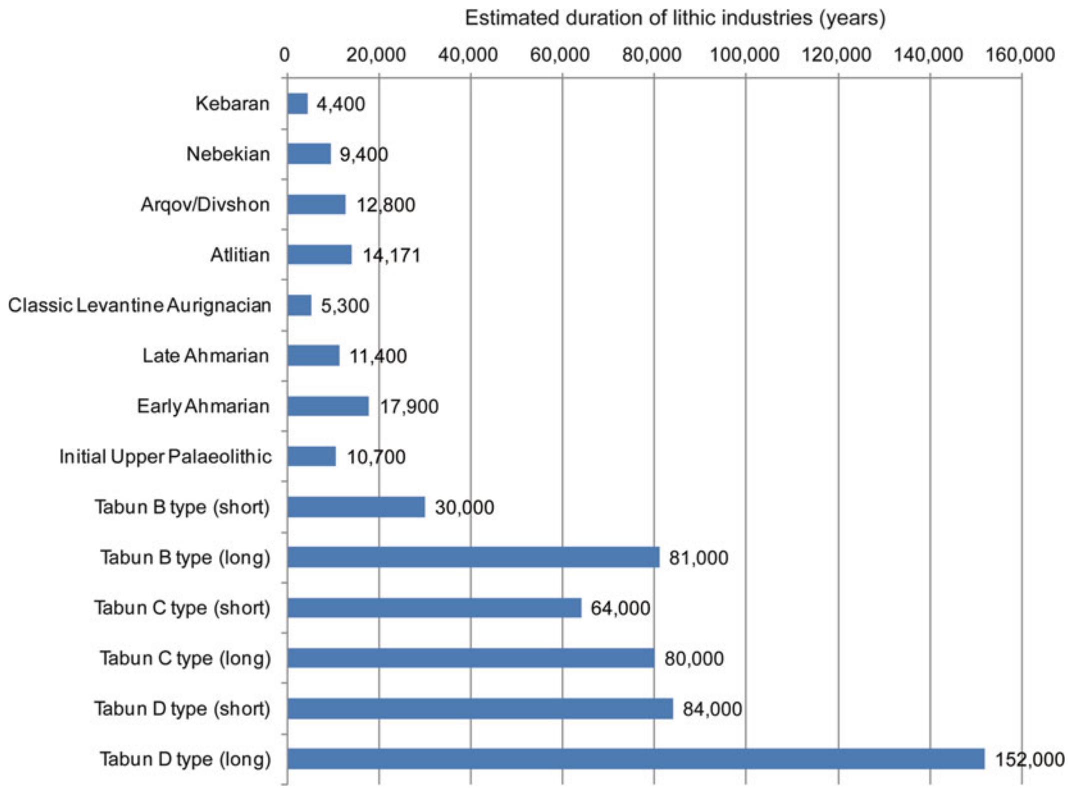


Fig. 4.12 Durations of the Middle, Upper, and early Epipalaeolithic industries in the Levant. Note that short and long chronological models are created for each of the MP industries (see Sect. 4.5 in the text)

time spans of Palaeolithic industries have recently been discussed by Bar-Yosef (2003), who shows that the approximate durations of lithic industries are longer for the MP and shorter for the UP and Epipalaeolithic periods. According to Bar-Yosef, this pattern indicates the "rigid teaching and transfer of knowledge within a closed society that persisted over the course of many generations among Middle Palaeolithic groups" (Bar-Yosef 2003, pp. 270–272). In contrast, during the Upper and Epipalaeolithic, "[f]aster changes… of operational sequences, and shifts in retouched tools…reflect flexible social systems, and rapidly increasing populations."

We estimated the duration of lithic industries from their radiomeric dates, that were screened for reliable dates, as described above (Tables 4.2 and 4.3). The selected dates were used to calculate the start and end dates as well as the duration of each lithic industry. The calculation was done using phase modeling in the Oxcal program (and partly by the Calpal program for some radiocarbon dates) with the 68% confidence level (Bronk Ramsey 2009; Danzeglocke et al. 2012). We made multiple models for the three MP industries because their radiometric dates, if taken at face value, could indicate different scenarios of either start or end date, although the short chronology that models sequential occurrences of the Tabun D/C/B industries without temporal overlap is more likely the case as discussed in the chronological examination. Strictly speaking, multiple models can also be considered for some UP and Epipalaeolithic industries due to the uncertainty and different views on the cultural affiliation of some lithic assemblages, as discussed earlier. However, the multiple scenarios for the UP and Epipalaeolithic periods are not discussed here because they do not affect their general comparison with the MP industries.

As a result, Fig. 4.12 shows the durations of the MP and UP industries in the Levant. Despite several different models, the duration of MP industries is longer than UP ones as expected from previous studies. It is notable that the duration of the IUP is closer to the UP pattern than the Tabun B-type. Does this pattern suggest that UP cultural changes (probably by *Homo sapiens*) were more rapid than that of the Tabun B-type industry, that is currently only associated with Neanderthal fossils? Although this observation may fit a stereotypical characterization of the MP and UP cultural patterns, we have to keep in mind that the criteria for classifying lithic industries usually differ between the MP and UP periods. The classification of the MP industries tends to be based on the characteristics of core reduction technology, while the identification of the UP industries puts more emphasis on the morphology and composition of retouched tools, that are amenable to finer scales of classification. In fact, from the perspective of core reduction technology, several Levantine UP blade industries, such as the IUP, the Early Ahmarian, the Late Ahmarian, and the Kebaran, can be grouped together in what is known as the Leptolithic Lineage (Marks 2003). The chronological span of the Leptolithic is comparable to the Tabun B-type industry.

Additionally, the apparent long duration of the Tabun C-type industry, associated with *Homo sapiens*, contradicts a conventional view that contrasts the slow culture change by Neanderthals with the more rapid shift by *Homo sapiens*. This study estimates that the Tabun C-type industry lasted from either 160 kya or 140 to 80 kya according to the methods described earlier. This could mean that this industry's interval was significantly longer than those of the UP industries despite their common association with *Homo sapiens*. Moreover, the time span of the Tabun C-type is apparently longer than the Tabun B-type. The time range of Qafzeh and Skhul occupations, where *Homo sapiens* fossils are actually associated with the Tabun C-type assemblages, is shorter than that of the whole Tabun C-type industry. TL dates of Qafzeh and Skhul are 102–85 kya and 119 ± 18 kya respectively (Valladas et al. 1998, p. 71), that are more or less confirmed by ESR dates. These radiometric dates correspond to MIS 5 and are consistent with the occurrences of Afro-Arabian micromammals in the faunal spectra from Qafzeh (Tchernov 1998). In this case, the duration of the Tabun C-assemblages at Qafzeh and Skhul is ca. 40,000 years, that is still distinctively longer than any UP industries, even considering the error range.

4.5.3.2 Cumulativeness of Culture Change

The cumulativeness of culture change is defined here as the continuity of some elements and the change in others from one culture to another. This aspect is considered significant in the cultural evolutionary model that considers learning behaviors (Borenstein et al. 2008) because the continuity may represent a result of social learning by creators of a new culture, while the change may indicate exploratory individual learning including innovations. Despite this theoretical expectation, it is difficult, in a practical sense, to assess the degree of continuity or change between lithic industries. Although this cannot be quantitatively analyzed by using the kinds of data in our database, it is discussed here on the basis of the chronological and geographic patterns of lithic industries.

The most likely case for cumulative cultural change, or at least technological continuity, is the cultural sequence from the IUP through the Early and Late Ahmarian to the Kebaran. As described above, these industries are generally considered as representing the local evolution of blade dominant technological traditions from Levallois-based technology through the development of prismatic blade-core reduction, to the microlithization of blade tools, labeled the Levantine Leptolithic Lineage by Marks (2003). This study examined the sequential chronological occurrence of these industries in the same geographic space covering more or less wide areas in the Levant (Figs. 4.3, 4.7, 4.8, and 4.10). Strictly speaking, the apparent technological continuity does not necessarily mean the continuity of local populations and could involve the population replacement if the preceding and the following groups share the same technology. However, this case does not contradict the notion of cumulative culture change if there was a contact between the two groups and hence the opportunity for the transmission of lithic technological knowledge.

Is such a cultural pattern observable for the Tabun B-type industry, that is often associated with Neanderthal fossils? In order to examine this question, a seriation analysis was conducted for some Tabun B-type assemblages from Amud, Kebara, and Dederiyeh, where Neanderthal fossils were discovered. Although the details of this study are published in another paper (Nishiaki et al. 2012b), the summary of the results relevant to this discussion is described here. Nishiaki et al. (2012b) examined frequencies of four different ways of core reduction, tool blank types and tool types by levels at each cave to see if there was any chronological pattern among the Tabun-B type assemblages. As a result, the core reduction method shows the clearest change according to the stratigraphic sequences at the three sites. At Kebara, the earlier phase is characterized by the dominance of convergent core flaking, typical of the Tabun B-type industry, followed by the later phase, in which the multiple flaking increases. At Amud in contrast, the convergent flaking occurs in the later phase, while in the earlier phase, multiple and opposed flaking are more frequent. At Dederiyeh Cave, the use of convergent flaking is dominant throughout the sequence. These stratigraphic changes in the core reduction method can be seriated from Amud through Dederiyeh to Kebara, that represents a diachronic technological change from a dominance of opposed and multiple flaking to an increase in convergent flaking, which then decreases in the last stage. This relative chronology is in accord with radiometric dates from the three sites, indicating that the Tabun B-type industry involved some degree of diachronic technological variability.

The primary issue is how these results are to be interpreted. One could argue that the pattern of changes (i.e., the increase in convergent flaking followed by its decrease) of the Tabun B-type can be aptly described as "fluctuation" rather than "accumulation," and thus differs from the directional development of blade technology (i.e., from the Levallois-based method, through the typical prismatic blades with small butts, to the microlithization) during the UP in the Levantine Leptolithic Lineage. Alternatively, one could also argue that the diachronic patterns of the core-reduction method in the Tabun B-type industry indicate the rate of technological change that is no less frequent, if not more, than the UP Leptolithic tradition.

In addition, it should be noted that there are UP industries that do not show chronological or geographic patterns indicative of cumulative culture change. In the Levantine case, these industries are the Classic Levantine Aurignacian, the Arqov/Divshon, the Atlitian, and the Nebekian. The chronological ranges of these industries are either discontinuous or clustered, and tend to occur in different geographic areas making it difficult to observe any culture-historical relationship with other industries. The apparent lack of cumulative culture change does not necessarily mean a specific type of learning strategies because it can result from a number of different backgrounds, including technological innovations/adaptations, an influx of ideas/traits from migrating populations, or a change of local cultures under the influence of different cultural groups. The cumulative culture change is not apparent either in some Tabun C-type assemblages associated with *Homo sapiens*, like Qafzeh and Skhul, where no stratigraphic technological patterns are observable (Boutié 1989; Hovers 2009).

4.6 Summary and Future Directions

Making plausible interpretations about prehistoric behavior, and past cultures in general, is not an easy task due to the fragmentary nature of archaeological remains, where one always encounters the problem of sample size. In an attempt to deal with these unavoidable conditions, we are constructing a database to organize currently available archaeological records relevant to the RNMH process. Through this database, we aim to obtain insights into prehistoric learning behavior by *Homo sapiens* and Neanderthals to examine whether learning behavior differed between the two groups. As part of this endeavor, this paper examined the MP and UP cultural variability in the Levant, focusing on the chronological and geographic patterns of lithic industries. These archaeological records were then discussed in terms of the anthropological events that took place in the Levant by reviewing the MP and UP fossil records. Lastly, this was followed by a discussion on the duration of lithic industries and the cumulativeness of culture change, that is considered a key variable in evolutionary models of learning behavior.

A simple comparison of the time span among lithic industries (Fig. 4.12) might suggest that the rate of technological changes by *Homo sapiens* during the UP is more rapid than those by Neanderthals (that produced the Tabun B-type industry during the MP). However, considering the use of different criteria for classifying MP and UP lithic industries, it can be argued that the duration of the UP blade tradition (i.e., Leptolithic Lineage) is comparable to that of the Tabun B-type. Another inconsistency with the conventional cultural distinction between *Homo sapiens* and Neanderthals is an apparently long chronological range of some Tabun C-type assemblages associated with *Homo sapiens*, such as Qafzeh and Skhul.

Changes that may represent the cumulative nature of cultural change are observable only for some UP lithic industries that constitute the Levantine Leptolithic Lineage and not for other UP industries or the Tabun C-type. The Tabun B-type industry, associated with Neanderthals, may show diachronic shifts in the core reduction method, that indicate the rate of technological change that is no less frequent than the UP industries, although the Tabun B-type pattern could be interpreted to represent "fluctuation" rather than "accumulation."

The above discussion suggests that the pattern of culture change by *Homo sapiens* and Neanderthals in the Levant is elusive and variable. It is elusive because it depends on the criteria and interpretations in the measurement of the rate and cumulativeness of culture change; and it is variable because some lithic industries may indicate rapid and cumulative changes while others do not. The latter case is represented by the Tabun B-type and C-type industries in the MP and the Classic Levantine Aurignacian, the Arqov/Divshon, the Atlitian, and the Nebekian in the UP and early Epipalaeolithic. As described earlier, the emergence of new lithic industries could have resulted from various factors including innovations by local populations, the influx of foreign groups who can either change or inherit preceding technological traditions, and changes by local groups under the social/cultural influence from surrounding populations. Because available data do not allow us to narrow down the range of relevant factors, it is difficult to identify specific types of learning strategies based on chronological and geographical patterns of lithic industries.

In an effort to augment the examination of cultural patterns associated with *Homo sapiens* and Neanderthals, we need to look beyond the Levant and collect more records from other regions. In particular, two essential aspects require further investigation: (1) the first is the chronological and geographical patterns of Neanderthals because this is limited to the Tabun B-type industry in the Levant. For this purpose, we are collecting relevant records from the European MP; (2) the second is an understanding of cultural variability by *Homo sapiens* during the MP because this is limited to some Tabun C-type assemblages in the Levant. For this purpose, we are constructing a database for Middle Stone Age cultures in Africa. These additional data should help us examine cultural variability by *Homo sapiens* and Neanderthals at a broader temporal and spatial scale so that we may contribute to a more accurate understanding of their cultural and behavioral evolution.

References

Akazawa T (1974) Palaeolithic assemblages from the Douara Cave site. In: Suzuki H, Takai F (eds) The Paleolithic site at Douara Cave in Syria (Part II). University of Tokyo Press, Tokyo, pp 1–167, The University Museum, The University of Tokyo, Bulletin 6

Akazawa T (2012) RNMH project series No. 001: RNMH project 2010–2014. RNMH Project Group, Tokyo

Akazawa T, Muhesen S (2002) Neanderthal burials: excavations of the Dederiyeh Cave, Afrin, Syria. KW Publications, Auckland

Aoki K (2012) Advanced individual learning – the key to replacement? In: Akazawa T (ed) RNMH project series No. 001: RNMH project 2010–2014. RNMH Project Group, Tokyo, pp 42–44

Barham L, Mitchell P (2008) The first Africans: African archaeology from the earliest toolmakers to most recent foragers. Cambridge University Press, Cambridge

Bar-Yosef O (1989) Geochronology of the Levantine Middle Palaeolithic. In: Mellars PA, Stringer CB (eds) The human revolution. Edinburgh University Press, Edinburgh, pp 589–610

Bar-Yosef O (1995) The origin of modern humans. In: Levy T (ed) The archaeology of society in the holy land. Leicester University Press, London, pp 110–121

Bar-Yosef O (2000) The Middle and early Upper Paleolithic in southwest Asia and neighboring regions. In: Bar-Yosef O, Pilbeam D (eds) The geography of Neandertals and modern humans in Europe and the Greater Mediterranean. Harvard University, Cambridge, pp 107–156

Bar-Yosef O (2003) Reflections on selected issues of the Upper Palaeolithic. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp 265–273

Bar-Yosef O, Belfer-Cohen A (2010) The Middle to Upper Palaeolithic transition in western Asia. In: Boyle KW, Gamble C, Bar-Yosef O (eds) The Upper Palaeolithic revolution in global perspective: papers in honour of sir Paul Mellars. McDonald Institute for Archaeological research, Cambridge, pp 85–101

Bar-Yosef O, Callander J (1999) The woman from Tabun: Garrod's doubts in historical perspective. J Hum Evol 37:879–885

Bar-Yosef O, Meignen L (2007) Kebara Cave, Mt. Carmel, Israel: the Middle and Upper Paleolithic archaeology, part I. Peabody Museum of Archaeology and Ethnology. Harvard University, Cambridge

Bar-Yosef O, Phillips JL (1977) Prehistoric investigations in Gebel Maghara, northern Sinai. Qedem 7. The Hebrew University, Jerusalem

Bar-Yosef O, Arnold M, Mercier N, Belfer-Cohen A, Goldberg P, Housley R, Laville H, Meignen L, Vogel JC, Vandermeersch B (1996) The dating of the Upper Paleolithic layers in Kebara Cave, Mt Carmel. J Archaeol Sci 23:297–306

Belfer-Cohen A, Goring-Morris N (2003) Current issues in Levantine Upper Palaeolithic research. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp 1–12

Belfer-Cohen A, Goring-Morris N (2007) From the beginning: Levantine Upper Palaeolithic cultural change and continuity. In: Mellars P, Boyle K, Bar-Yosef O, Stringer C (eds) Rethinking the human revolution. University of Cambridge, Cambridge, pp 199–206

Bergman C (1981) Point types in the Upper Palaeolithic sequence at Ksar 'Akil, Lebanon. In: Cauvin J, Sanlaville P (eds) Préhistoire du Levant. Centre National de la Recherche Scientifique, Paris, pp 319–330

Bergman C (2003) Twisted debitage and the Levantine Aurignacian problem. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp 185–195

Bergman C, Stringer C (1989) Fifty years after: Egbert, an early Upper Palaeolithic juvenile from Ksar Akil, Lebanon. Paléorient 15(2):99–111

Borenstein E, Feldman MW, Aoki K (2008) Evolution of learning in fluctuating environments: when selection favors both social and exploratory individual learning. Evolution 62(3):586–602

Bourke S (1997) Two human teeth from Ras el-Kelb. In: Copeland L, Moloney N (eds) The Mousterian site of Ras el-Kelb, Lebanon, BAR International Series 706. Hadrian Books, Oxford, pp 68–72

Boutié P (1989) Etude technologique de l'industrie moustérienne de la Grotte de Qafzeh (près de Nazareth, Israël). In: Bar-Yosef O, Vandermeersch B (eds) Investigations in south Levantine prehistory. BAR International Series 497, Oxford, pp 213–229

Bronk Ramsey C (2009) Bayesian analysis of radiocarbon dates. Radiocarbon 51(1):337–360

Clark GA, Schuldenrein J, Donaldson M, Schwarcz H, Rink W, Fish S (1997) Chronostratigraphic contexts of Middle Paleolithic horizons at the Ain Difla Rockshelter (WHS 634), west-central Jordan. In: Gebel HG, Kafafi Z, Rollefson G (eds) The prehistory of Jordan II: perspectives from 1997. Ex oriente, Berlin, pp 77–100

Coinman N (2003) The Upper Palaeolithic of Jordan: new data from the Wadi al-Hasa. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp 151–170

Coinman N, Henry D (1995) The Upper Paleolithic sites. In: Henry D (ed) Prehistoric cultural ecology and evolution: insights from southern Jordan. Plenum, New York, pp 133–214

Copeland L (1975) The Middle and Upper Palaeolithic of Lebanon and Syria in the light of recent research. In: Wendorf F, Marks AE (eds) Problems in prehistory: north Africa and the Levant. Southern Methodist University Press, Dallas, pp 317–350

Copeland L (2000) Forty-six Emireh points from the Lebanon in the context of the Middle to Upper Paleolithic transition in the Levant. Paléorient 26(1):73–92

Copeland L (2003) The Levantine Upper Palaeolithic: a commentary on contributions to the Philadelphia symposium. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp 242–248

Danzeglocke U, Jöris O, Weninger B (2012) CalPal-2007online. http://www.calpal-online.de/ Accessed 5 May 2012

Dennel R (2009) The Palaeolithic settlement of Asia. Cambridge University Press, Cambridge

d'Errico F, Henshilwood C, Lawson G, Vanhaeren M, Tillier A-M, Soressi M, Bresson F, Maureille B, Nowell A, Lakarra J, Backwell L, Julien M (2003) Archaeological evidence for the origins of language, symbolism and music. An alternative multidisciplinary perspective. J World Prehist 17:1–70

Douka K, Bergman CA, Hedges REM, Wesselingh FP, Higham TFG (2013) Chronology of Ksar Akil (Lebanon) and implications for the colonization of Europe by anatomically modern humans. PLoS ONE 8(9):e72931. doi:10.1371/journal.pone.0072931

Ferring CR (1988) Technological change in the Upper Paleolithic of the Negev. In: Dibble H, Montet-White A (eds) Upper Pleistocene prehistory of western Eurasia. The University Museum, University of Pennsylvania, Philadelphia, pp 333–348

Fox J, Coinman N (2004) Emergence of the Levantine Upper Paleolithic. In: Brantingham P, Kuhn S, Kerry K (eds) The early Upper Paleolithic beyond western Europe. University of California Press, Berkeley, pp 97–112

Garrod DAE, Bate DMA (1937) The Stone Age of Mount Carmel: excavations at the Wady el-Mughara, vol I. AMS, New York

Gilead I (1981) Upper Palaeolithic tool assemblages from the Negev and Sinai. In: Cauvin J, Sanlaville P (eds) Préhistoire du Levant. Centre National de la Recherche Scientifique, Paris, pp 331–342
Gilead I (1991) The Upper Paleolithic period in the Levant. J World Prehist 5(2):105–154
Gilead I (1995) The foragers of the Upper Paleolithic Period. In: Levy T (ed) The archaeology of society in the holy land. Leicester University Press, London, pp 124–137
Goren-Inbar N (1990) Quneitra: a Mousterian site on the Golan Heights. Hebrew University, Jerusalem
Goring-Morris N (1995) Complex hunter/gatherers at the end of the Paleolithic (20,000–10,000 BP). In: Levy T (ed) The archaeology of society in the holy land. Leicester University Press, London, pp 141–167
Goring-Morris N, Belfer-Cohen A (2006) A hard look at the "Levantine Aurignacian: how real is the taxon? In: Bar-Yosef O, Zilhão J (eds) Towards a definition of the Aurignacian. Instituto Português de Arqueologia, Lisbon, pp 297–316
Grün R, Stringer CB (2000) Tabun revisited: revised ESR chronology and new ESR and U-series analyses of dental material from Tabun C1. J Hum Evol 39:601–612
Henry O (1989) From foraging to agriculture: the Levant at the end of the Ice Age. University of Pennsylvania Press, Philadelphia
Henry O (1995) Prehistoric cultural ecology and evolution. Plenum, New York
Henry O (2004) Neanderthal in the Levant: behavioral organization and the beginnings of human modernity. Continuum, London
Hovers E (2009) The lithic assemblages of Qafzeh Cave. Oxford University Press, Oxford
Hovers E, Kuhn S (2006) Transitions before the transition: evolution and stability in the Middle Paleolithic and Middle Stone Age. Springer, New York
Hovers E, Rak Y, Lavi R, Kimbel WH (1995) Hominid remains from Amud Cave in the context of the Levantine Middle Paleolithic. Paléorient 21(2):47–61
Jelinek A (1981) The Middle Paleolithic in the southern Levant from the perspective of the Tabun Cave. In: Cauvin J, Sanlaville P (eds) Préhistoire du Levant. Centre National de la Recherche Scientifique, Paris, pp 265–280
Kondo Y, Kadowaki S, Kato H, Naganuma M, Ono A, Sano K, Nishiaki Y (2012) Network computing for archaeology: a case study from the 'Replacement of Neanderthals by Modern Humans' database project. In: Verhagen P (ed) Revive the past. Proceedings of the 39th international conference of computer applications and quantitative methods in archaeology, Beijing, China, 12–16 April 2011. Amsterdam University Press, Amsterdam, pp 227–236
Kuhn SL, Stiner MC, Güleç E, Özer I, Yılmaz H, Baykara I, Ayşen A, Goldberg P, Martínez Molina K, Ünay E, Suata-Alpaslan F (2009) The early Upper Paleolithic occupations at Üca ğızlı Cave (Hatay, Turkey). J Hum Evol 56:87–113
Le Tensorer J-M, von Falkenstein V, Le Tensorer H, Muhesen S (2008) Hummal: a very long Paleolithic sequence in the steppe of central Syria - considerations on Lower Paleolithic and the beginning of Middle Paleolithic. In: Le Tensorer J-M, Jagher R, Otte M (eds) The Lower and Middle Palaeolithic in the middle east and neighbouring regions. ERAUL 126, Liege, pp 235–248
Marks A (1981) The Upper Paleolithic of the Negev. In: Cauvin J, Sanlaville P (eds) Préhistoire du Levant. Centre National de la Recherche Scientifique, Paris, pp 299–304
Marks A (1983) Prehistory and paleoenvironments in the central Negev, Israel: the Avdat/Aqev area, part 3. Southern Methodist University, Dallas
Marks A (2003) Reflections on Levantine Upper Palaeolithic studies: past and present. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp 249–264
Marks A, Kaufman D (1983) Boker: the artifacts. In: Marks A (ed) Prehistory and paleoenvironments in the central Negev, Israel: the Avdat/Aqev area, part 3. Southern Methodist University, Dallas, pp 283–329
Marks A, Volkman P (1986) The Mousterian of Ksar Akil: Levels XXVIA through XXVIIIB. Paleorient 12(1):5–20
Meignen L, Bar-Yosef O (1992) Middle Paleolithic lithic variability in Kebara Cave, Mount Carmel, Israel. In: Akazawa T, Aoki K, Kimura T (eds) The evolution and dispersal of modern humans in Asia. Hokusen-sha, Tokyo, pp 129–148
Nadel D (2003) The Ohalo II flint assemblage and the beginning of the Epipalaeolithic in the Jordan Valley. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp 216–229
Nishiaki Y (2012) Archaeological research of the learning behaviours of the Neanderthals and early modern humans. In: Akazawa T (ed) RNMH project series No. 001: RNMH project 2010–2014. RNMH Project Group, Tokyo, pp 32–36
Nishiaki Y, Kadowaki S, Kume S, Shimogama K (2012a) Archaeological survey around Tell Ghanem Al-'Ali (V). Al-Rafidan 33:1–6
Nishiaki Y, Kanjo Y, Muhesen S, Akazawa T (2012b) Temporal variability of Late Levantine Mousterian assemblages from Dederiyeh Cave, Syria. Eurasian Prehist 9(1/2):3–26
Nishiaki Y, Kanjo Y, Muhesen S, Akazawa T (2011) Recent progress in Lower and Middle Palaeolithic research at Dederiyeh Cave, northwest Syria. In: Le Tensorer J-M, Jagher R, Otte M (eds) The Lower and Middle Palaeolithic in the Middle East and neighbouring regions. ERAUL 126, Liège, pp 67–76
Neuville R (1951) Le Paléolithique et le Mésolithique du Désert de Judée. Archives l'Institut de PaléontologieHumaine, Paris
Ohnuma K (1988) Ksar 'Akil, Lebanon: a technological study of the earlier Upper Palaeolithic levels of Ksar 'Akil, vol III. BAR International Series 426, Oxford, Levels XXV–XIV
Olszewski D (2006) Issues in the Levantine Epipaleolithic: the Madamaghan, Nebekian and Qalkhan (Levant Epipaleolithic). Paléorient 32(1):19–26
Olszewski D (2008) The Palaeolithic period, including the Epipalaeolithic. In: Adams RB (ed) Jordan: an archaeological reader. Equinox, London, pp 35–69
Olszewski D (2009) Whither the Aurignacian in the Middle East? Assessing the Zagros Upper Paleolithic. In: Otte M, Biglari F, Jaubert J (eds) Iran Palaeolithic, vol 1968, BAR International Series., pp 39–45
Olszewski D, Dibble H (2006) To be or not to be Aurignacian: the Zagros Upper Paleolithic. In: Bar-Yosef O, Zilhão J (eds) Towards a definition of the Aurignacian. InstitutoPortuguês de Arqueologia, Lisbon, pp 355–373
Phillips JL (1988) The Upper Paleolithic of the Wadi Feiran, southern Sinai. Paléorient 14(2):183–200
Ploux S, Soriano S (2003) Umm el Tlel, une séquence du paléolithique supéieur en Syrie central. Industries lithiques et chronologie culturelle. Paléorient 29(2):5–34
Quam R, Smith F (1998) A reassessment of the Tabun C2 mandible. In: Akazawa T, Aoki K, Bar-Yosef O (eds) Neanderthals and modern humans in western Asia. Plenum, New York, pp 405–421
Rak Y (1998) Does any Mousterian cave present evidence of two hominid species? In: Akazawa T, Aoki K, Bar-Yosef O (eds) Neanderthals and modern humans in western Asia. Plenum, New York, pp 353–366
Rebollo NR, Weiner S, Brock F, Meignen L, Goldberg P, Belfer-Cohen A, Bar-Yosef O, Boaretto E (2011) New radiocarbon dating of the transition from the Middle to the Upper Paleolithic in Kebara Cave, Israel. J Archaeol Sci 38:2424–2433

Schwarcz H, Blackwell B, Goldberg P, Marks AE (1979) Uranium series dating of travertine from archaeological sites, Nahal Zin, Israel. Nature 277:558–560

Shea J (2003) The Middle Paleolithic of the east Mediterranean Levant. J World Prehist 17(4):313–394

Smith P (1995) People of the holy land from prehistory to the recent past. In: Levy T (ed) The archaeology of society in the holy land. Leicester University Press, London, pp 58–74

Suzuki H, Takai F (1970) The Amud man and his cave site. The University of Tokyo, Tokyo

Tchernov E (1998) The faunal sequence of the southwest Asia Middle Paleolithic in relation to hominid dispersal events. In: Akazawa T, Aoki K, Bar-Yosef O (eds) Neanderthals and modern humans in western Asia. Plenum, New York, pp 77–94

Valladas H, Joron JL, Valladas G, Arensburg B, Bar-Yosef O, Belfer-Cohen A, Goldberg P, Laville H, Meignen L, Rak Y, Tchernov E, Tillier AM, Vandermmeersch B (1987) Thermoluminescence dates for the Neanderthal burial site at Kebara in Israel. Nature 330:159–160

Valladas H, Mercier N, Froget L, Hovers E, Joron J-L, Kimbel WH, Rak Y (1999) TL dates for the Neanderthal site of the Amud Cave, Israel. J Archaeol Sci 26:259–268

Valladas H, Mercier N, Joron JL, Reyss JL (1998) Gif laboratory dates for Middle Paleolithic Levant. In: Akazawa T, Aoki K, Bar-Yosef O (eds) Neanderthals and modern humans in western Asia. Plenum, New York, pp 69–75

van der Plicht J, van der Wijk A (1989) Uranium and thorium in fossil bones: activity ratios and dating. Appl Geochem 4:339–342

Williams J (2003) An examination of Upper Palaeolithic flake technologies in the marginal zone of the Levant. In: Goring-Morris AN, Belfer-Cohen A (eds) More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp 196–208

Williams J, Bergman C (2010) Upper Paleolithic levels XIII-VI (A and B) from the 1937–1938 and 1947–1948 Boston College excavations and the Levantine Aurignacian at Ksar Akil, Lebanon. Paléorient 36(2):117–161

Ziaei M, Schwarcs HP, Hall CM, Grün R (1990) Radiometric dating at the Mousterian site at Quneitra. In: Goren-Inbar N (ed) Quneitra: a Mousterian site on the Golan Heights. Hebrew University, Jerusalem, pp 232–235

Zilhão J (2007) The emergence of ornaments and art: an archaeological perspective on the origins of "behavioral modernity". J Archaeol Res 15:1–54

5 The Middle to Upper Paleolithic Transition in Siberia: Three Regional Sketches for Replacement

Hirofumi Kato

Abstract

This article considers aspects of the replacement of Neanderthals by Modern humans through the archaeological record of three regions in west, central, and east Siberia: the Urals, the Altai, and Lake Baikal. In the process of constructing the database for the *Replacement of Neanderthals by Modern Humans (RNMH)* project, the archaeological resources from those areas were found to be relatively enriched. Here, I focus on the Middle to Upper Paleolithic transition period, and review the aspects of the transition/replacement in each area. In conclusion, I can point to distinct regional variations in the process transition/replacement that were developed in the Altai, the Urals, and the Lake Baikal.

Keywords

Diversity of techno-complex • Early upper paleolithic • Human colonization • Middle paleolithic • Siberia

5.1 Introduction

Siberia acts as a the stage where the quality and flexibility of environmental adaptation behaviour including technology and cognitive ability are equally tested for archaic human including such Neanderthals, as well as Modern humans (Fig. 5.1).

The RNMH project is aimed at investigating the differences in learning ability between Neanderthals and modern humans in particular. This learning ability had an effect on the survival of the two human groups, when they migrated into the frontier and were confronted with environmental crisis. The Human presence in Siberia, has recently, been pushed back to the early period. Peopling of the Arctic circle has also became the earlier than is conventionally assumed (approximate 40,000–30,000 BP) (Pavlov et al. 2004). In the Altai cave sites have revealed the new anthropological and genealogical records on human evolution (Krause et al. 2010; Gibbons 2011).

Today, it is not reasonable to simple assumed that Neanderthals were inferior in ability modern humans. At present, it is not reasonable to be considered that Defined in a general way as the Middle Paleolithic has long been considered as “a period of flake-based industry characterized by an important stability in tool types.” However, the Middle Paleolithic demonstrates that the concept of a dichotomy between simple and complex systems is not relevant in the Middle Paleolithic production (Meignen et al. 2009). Consequently, it is important to organize aspects of the Middle to Upper Paleolithic transition through archaeological records, and to recognize the chronological and geographical variabilities of their techno-complexes.

In this paper I would like to consider the next following two aspects in the Altai, the Urals, and the Lake Baikal:

1. Technological diversity in the Siberian Middle Paleolithic.
2. Highly flexible technology and tools, which adapted with environmental changes.

H. Kato (✉)
Hokkaido University Center for Ainu and Indigenous Studies,
Kita-ku, Sapporo, Hokkaido 060-0808, Japan
e-mail: h-kato@let.hokudai.ac.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_5, © Springer Japan 2013

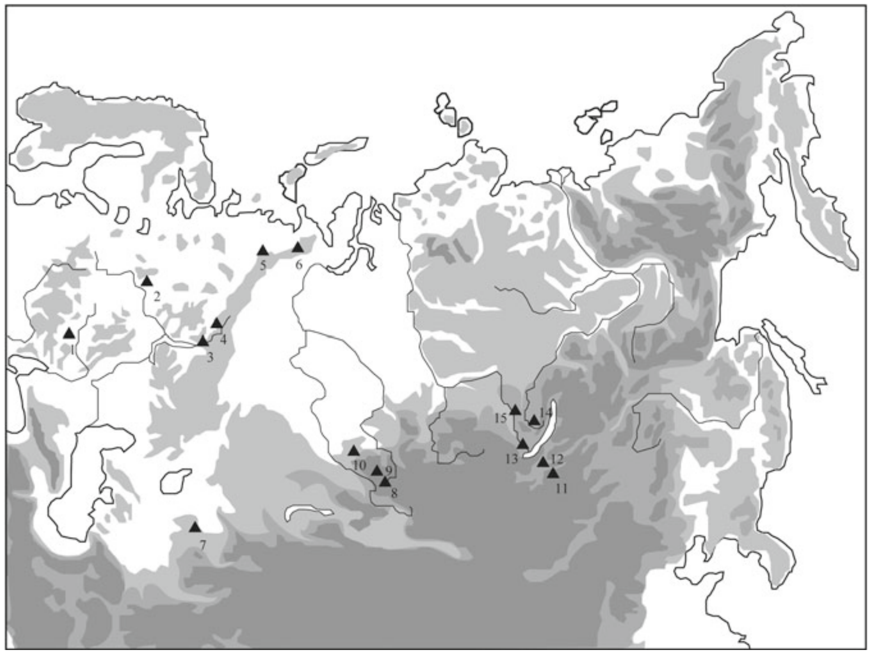


Fig. 5.1 Map of Siberia showing the locations of sites mentioned in text. *1*: Kostenki, *2*: Sungir, *3*: Zaozer'e, *4*: Garchi 1, *5*: Byzovaya, *6*: Mammontovaya Kurya, *7*: Teshik Tashi, *8*: Kara Bom, *9*: Denisova and Ust'-Karakol 1, *10*: Okladnikov, *11*: Pozvonkaya, *12*: Kamenka, *13*: Shapova, *14*: Makarovo 4, *15* Bol'shoj Narin 1

5.2 Human Colonization to the North in the Urals

Until the 1980s, the earliest peopling of the Ural mountains was not assumed to date prior to the last interglacial. Although, the earliest human presence from the south parkland-steppe zone of Siberia documented during the last 20 years (Chlachula 2010; Pavlov et al. 2004).

The initial peopling of the Urals is closely linked with the Palaeolithic expansion from the East European Plain, presumably intensifying during the climatically favourable MIS 5 (Chlachula 2010). In the Kama region on the western side of the Urals, currently have been found several Early and Middle Paleolithic sites such as Ganichata I, Borisovo, Sludka, Illinsk and others. The evidence consists of a few artefacts from Elniki II, which were found in a loess sequence below the last interglacial soil, and thus must be older than OIS5e, no later than 125,000 years ago (Guslitser and Pavlov 1993).

From the site of Garchi 1 site is located on the right bank of Kami basin (59°04'N and 56°07'E). Two cultural layers were found. The upper complex is related to the Kostenki-Streletskaya culture of the Upper Paleolithic, while the lower complex is related to the Middle Paleolithic. The lower complex have been uncovered from a stratum that is older than 60,000 years ago. (Pavlov et al. 2004).

A stratigraphically consistent series of TL dates for the 5 m of loess sediments suggests that the lower find layer is more than 66,000 ± 9,600 BP. The lithic complex from Garchi 1 site includes cores, skleblos, skleblo-knives, leaf-shaped bifaces, borer, point, projectile points, and flakes (Fig. 5.2: 16–23). Particularly characteristics of this complex is the category of retouched tools on the primary and secondary flakes. Pavel Pavlov has pointed out that this complex contains bifacial skleblo and knife similar to the Keimesser group (Fig. 5.2: 1). Based on overall trends of the lithic complex from Garchi 1 site, including bifacial tools and Levallois flakes, and a typical *déjeté*, he also considers the influence of the eastern Micoquian-type assemblage (Pavlov et al. 2004; Pavlov 2009). A lithic complex similar to that of Garchi 1 site was also found at the site of Peshchernyj Log (58°10'N and 56°31'E) in the lower basin of Chusovaya river (Pavlov et al. 2004).

5.2.1 The Middle to Upper Paleolithic Transition in the Urals

In the Urals, sites that have been related to the early Upper Paleolithic include Mamontova Kurya, the upper complex from Garchi 1, Byzovaya, Bliznetsova, and Zaozel'e.

Mamontova Kurya site is located on the southern bank of the Usa river at the Arctic circle (66°34'N and 62°25'E). This site has been radiocarbon dated to 32,000–40,000 uncalibrated BP, corresponding to 35,000–47,000 cal BP (Svendsen et al. 2010), and is believed to represent the oldest reported evidence of human occupation in the European Arctic (Svendsen and Pavlov 2003). The 123 mammals bones from this site include mammoth, reindeer, horse, and wolf. Through geo-archaeological survey, Pavlov concluded that archaeological materials from this site were located in a secondary context due to redeposition (Pavlov et al. 2004; Pavlov 2009; Svendsen et al. 2010).

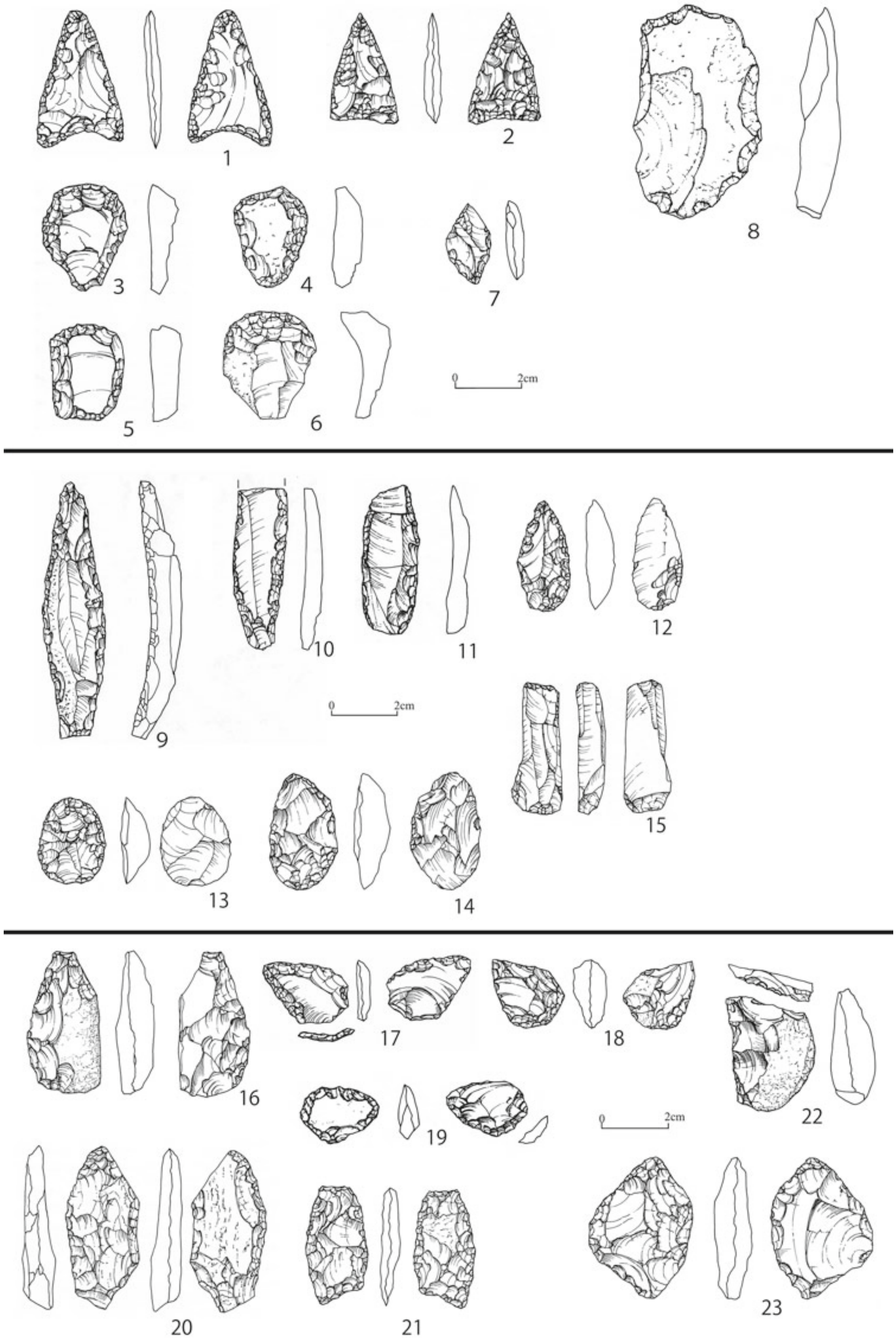


Fig. 5.2 Middle to Upper Paleolithic transition industry in Urals. *1–8*: Upper complex from Garchi 1, *9–15*: Zaozer'e, *16–23*: Lower complex from Garchi 1. (modified from Pavlov 2004)

Most of the artefacts are flakes, but artefacts also include a scraper and a bifacial tool.

These lithic tools are reminiscent of both the Middle Paleolithic (Mousterian) as well as the early Upper Paleolithic in Eastern Europe. Pavel Pavlov and Janusz Kozlowski are considered this complex to be related to the Stretskian in the Russian plain (Kozlowski 2010; Pavlov 2009).

The Byzovaya site is situated on the right bank of the Pechola river (65°01'N and 57°25'E). This site has been known and investigated since 1963, and found more than 4,000 mammal bones have been found dominated by mammoth remains, as well as around 300 artefacts A series of radiocarbon dates on bones yielded ages in the range 29,000–30,000 uncalibrated BP, with a mean of approximately 28,302±820 uncalibrated BP, corresponding to 34,580–31,370 cal BP (Svendsen et al. 2010). The lithic complex can be divided into two techno-morphological groups: Middle and Upper Paleolithic. The Middle Paleolithic group include some scrapers on blades, backed knives, “Keimesser-type” knives, and some bifacial tools. On the other hand, Upper Paleolithic group consist of end scrapers on blades, angle burins on blades, pieces esquilles, points and leaf points (Pavlov 2009).

The site of Zaozer'e is located on the left bank of the river Chusovaya, apart of the Kami reservoirs (58°09'N and 56°59'E). Radiocarbon dates on utilized bones have provided ages 30,100–35,100 uncalibrated BP, corresponding to 34,700–41,100 cal BP (Svendsen et al. 2010). The excavations have yielded rich faunal remains including horse, woolly rhinoceros, mammoth, reindeer, and hare. The archaeological finds consist of 1,774 lithics including 77 tools and nine cores, also found here four bone and antler tools, two pendants made of freshwater shell, and pieces of ochre (Pavlov 2009).

Primary reduction strategy is characterized by three preforms and two fragments of prismatic cores. The characteristic feature of the Zaozer'e lithic complex is the use of the blade reduction strategy technique with double-platform prismatic cores. Besides the blade technique a flake reduction technique was also used for the blanks of all kinds of end-scrapers including thick end-scrapers representing an Aurinacian tradition (Fig. 5.2: 9–15). Furthermore, there were side-scrapers including bifacial and oval examples (Fig. 5.2: 13–14). The most distinctive tools are Chatelperronian-like backed tools (Fig. 5.2: 1), blades with a lateral retouch (Pavlov et al. 2004). The Chatelperonian-like backed tools are not included in the Byzovaya complex (Pavlov et al. 2004).

The co-occurrence of the double-platform blade reduction strategy and specific backed tools has no direct analogues in any known early Upper Paleolithic industry in Eastern Europe (Kozlowski 2010). Pavel Pavlov has also pointed out the characteristics of this complex as the co-occurrence of two different techno-morphological groups: Aurinacian based on a blade reduction strategy, and the Szeletian techno-complex based on bifacial technique (Pavlov 2009).

The upper complex from Garchi I has yielded a large number of finds approximately 6,000 artefacts, including approximately 200 tools, and some poorly preserved faunal remains of horse and reindeer. Most of finds were concentrated near two clear fireplaces where have been interpreted as the remains of a dwelling structure (Pavlov 2009). It is dated to 28,800±800 uncalibrated BP, corresponding to 34,700–41,100 cal BP (Svendsen et al. 2010).

The primary reduction strategy is characterized by flat parallel cores. Most of blank of retouched tool based on blades (Fig. 5.2: 1–8). Scraper dominates the tool kits, and includes less numerous typical Sugirian bifacial triangular leaf points (Fig. 5.2: 1–2). This is typical of the Streletskian-Sungirian complex (Pavlov et al. 2004; Kozlowski 2010).

5.2.2 Repeated Human Colonization of the Urals

The earlier northward expansion west of the Urals may have been related to the diversity of the environment there, which must have occurred frequently during the late Pleistocene, no younger than 130 ka BP. According to the view of Pavlov, there were four colonization events to the Urals (Pavlov 2009). The first peopling into this region is related with the pebble industry such as see at El'niki II. Since that time, archaeological records suggest that several human migrations to this region occurred.

The second human migration is related to the Middle Paleolithic Mousterian complex during the period 130,000–100,000 BP. The Middle Paleolithic complex refers to the “Keilmesser group” or eastern Micoquian.

The third human migration is related to the early Upper Paleolithic (41,000–31,000 cal BP). The earliest evidences of this stage (41,000–34,000 cal BP) are represented at Zaozer'e and Mamontova Kurya. A small number of artefacts from Mamontova Kurya are insufficient to describe its cultural characteristics. The only possibility is that these artefacts are related to the Szeletsian techno-complex.

The lithic complex from Zaozer'e is a highly specific expression of the evolution of a separate cultural tradition in the early Upper Paleolithic of Eastern Europe. This industry has combined two techno-complex elements: Aurinacian and Szeletian. The following stage of the early Upper Paleolithic (34,000–31,000 cal BP) includes the upper complex from Garchi 1, Byzovaya, Bloznetsova cave. These traditions at this stage are related to the Streletskian-Sugirian (or the Kostenki-Streletskian).

As mentioned above, the Middle to Upper Paleolithic transition in the Urals is extremely unique. This feature can be closely related to the local original landscape where relatively short distances provide a combination of the plains in the west, and gently undulating foothills crossed by large rivers in the middle of the Urals. Such a diverse environment must have been highly attractive to the various species of herd animals of the mammoth steppe and hence to their hunters, both in the Middle, as well as in the Upper Paleolithic.

This background of repeated migrations and adaptive behaviours of several human groups itself would have affected the characteristics of the local environment and the distribution of resources in this region.

5.3 The Middle to Upper Paleolithic Transition in the Altai

5.3.1 Middle Paleolithic in the Altai

Southern parts of Siberia, especially, the Altai are the best-investigated area in Siberia. This territory was populated no later than 800,000 years ago (Derevianko and Shunikov 2005). According to the opinion of Anatoli Derevianko, however, the first migrant groups evidently became extinct in the Altai after 500,000 BP. At about 300,000 BP, a new group of archaic humans arrived in the Altai, introducing an entirely novel industry marked by Levallois and parallel techniques for primary reduction.

In the Altai, as a result of 30 years of studies, in nine cave sites (Denisova, Strashnaya, Okladnikov, Ust-Kanskaya, Kaminnaya, Chagyrskaya, Biyke, Maloyalomanskaya, and Iskra) as well as ten open-air sites (Ust-Karakol, Anui-1–3, Kara-Bom, Kara-Tensh, Tyumechin-1–4, Ushlep-6, etc.), the chronological interval from 100,000 to 30,000 BP well represented.

At Denisova Cave (51°23"N, 84°40"E), the earliest artefacts presumably attributable to the Late Acheulian period of the early Middle Paleolithic were found in stratum 22 radiocarbon dated to 282,000 ± 56,000 BP by RTL dating method. Strata 20–12 are Middle Paleolithic and strata 11 and 9 belong to the Upper Paleolithic. The earliest strata 22 and 21 with artefacts demonstrating the Levallois technique are dated to 280,000–150,000 BP by RTL (Derevianko 2010a). The earliest industry from Denisova Cave demonstrates Levallois features in primary reduction and a preference for the use of flakes as blanks for tool manufacture. Various types of *racloirs* and notched-denticulate tools predominate in the tool kit. The lithic complex Ust-Karakol-1 also has similar trends. The lithic complex from stratum 19 show parallel edges on the dorsal face and a prepared platform. Categories such as *racloirs* with longitudinal and convergent edges, and notched tools with Clactonian and retouched *encoches* have been identified within the tool kit (Derevianko 2010a).

Kara-Bom site is located in the Ursul valley (50°43"N, 85°42"E), 150 km from Denisova cave. Two Middle Paleolithic and six Upper Paleolithic stratigraphic units have been identified (Derevianko et al. 1998). The Middle Paleolithic units yielded cores and Levallois point and flake cores. All of these cores are of the flat-face type. A significant proportion of the tools were made on blades. Horizon 2 refers to the Middle Paleolithic, underlying a lithological layer with ESR date of 62,200 BP, and has yielded a set of Levallois Mousterian tools constituting 32 % of total tool kit, while the proportion of Upper Paleolithic tools is 16 %.

On the basis of presence of these variations, Middle Paleolithic industries in the Altai have been classified into two major industries: industries with predominantly Mousterian technology and industries with distinct Levallois tools (Shunikov 2005).

The Mousterian group includes lithic complexes founded from Denisova cave and the open-air site of Tiumechin-1. The primary reduction strategy from this group is predominantly parallel and radial production method. Levallois reduction strategy is apparent on only a few artefacts, especially within the Tiumechin-1 collection. In general, the impact of the Levallois reduction strategy on the technological process seems insignificant. The majority of tools were produced on medium-sized and short spalls. Retouched tools are dominated by Mousterian and notched-denticulate tools. Levallois implements are morphologically distinct but scarce. Various *racloirs* including “Charentien,” diagonal, and *déjeté* varieties, are most numerous. On the basis of the common techno-typological features, Siberian specialists propose categorizing these collections as the Denisova variant of the Altai Mousterian.

The Levallois group in the Altai includes the sites of Kara-Bom, Ust'-Karakol 1, Anui 3, and Ust'-Kan Cave. These industries are characterized by the predominance of Levallois reduction strategy, a developed technique of blade detachment, comparatively large numbers of tools fashioned on blades and Levallois spalls, a rather small variety of tool types where blades and non-retouched Levallois points are most numerous, and relatively few Mousterian forms.

5.3.2 Two Early Upper Paleolithic Industries and *Sibiryachikha* Industry

The final stage of development of the complex from Denisova is illustrated by the artefacts from stratum 11 (Derevianko 2010a). The Max Planck Institute, Germany has dated seven bone fragments found from layer 11 in the east and south galleries. For of the seven dates are infinite dates meaning older than 50,000 BP, whereas three dates are finite dates between 30,000 and 16,000 uncalibrated BP. A rib with incisions and a bone projectile point blank are about 30,000 and 23,000 uncalibrated BP respectively (Reich et al. 2010). Together with three previous dates this shows that layer 11 dates to >50,000 to 16,000 uncalibrated BP.

The major characteristic feature of the industry from stratum 11 is the equal proportions of Middle and Upper Paleolithic tools in this complex. Within the collection of typologically distinct retouched tools, the share of Mousterian points and various side-scrapers is 22.5 %. This category is dominated by longitudinal side-scrapers with one cutting

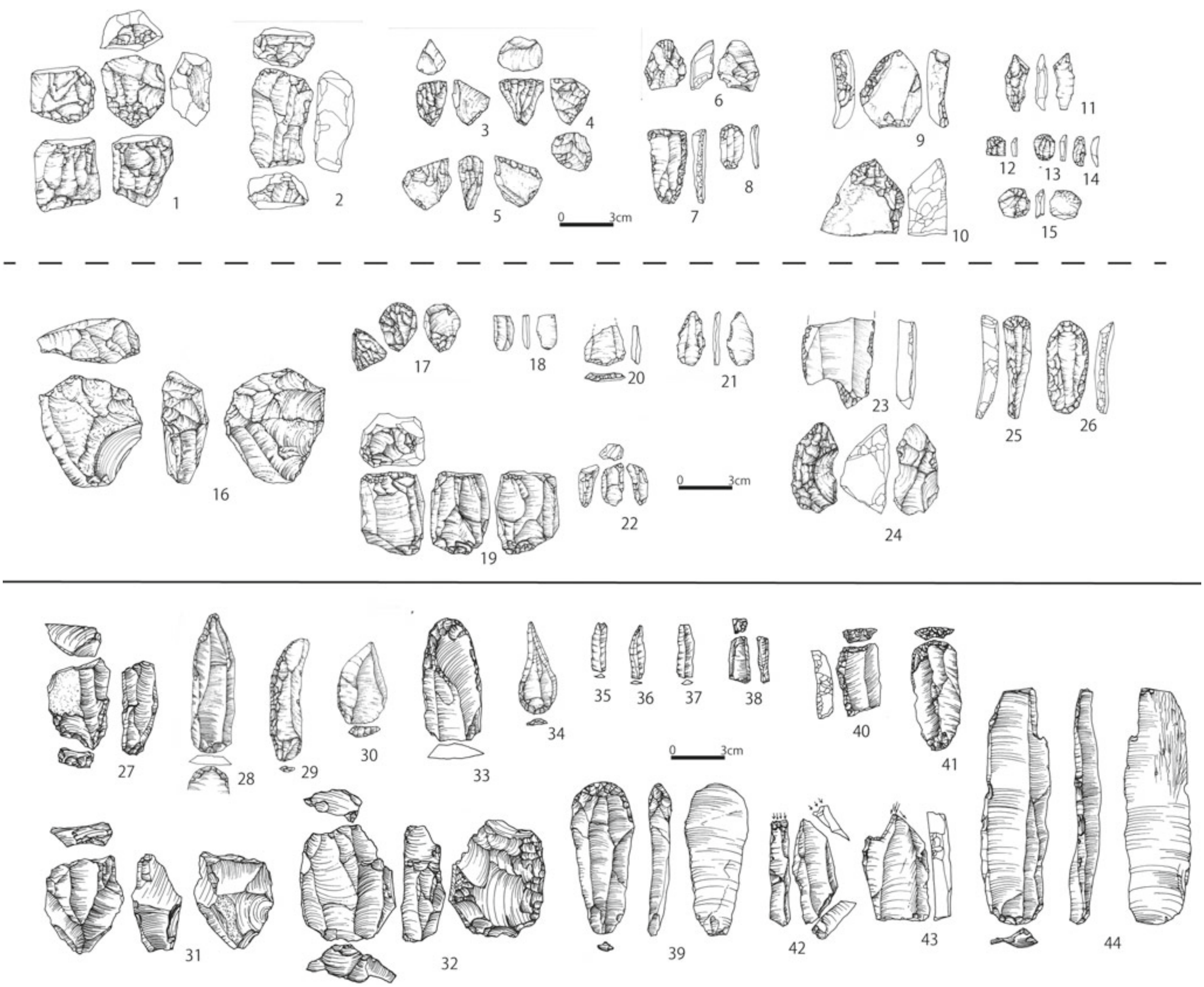


Fig. 5.3 Early Upper Paleolithic complexes in Altai. *1–26*: Ust-Karakol 1 industry (*1–15*: cultural horizon 9; *16–26*: cultural horizon 11), *27–44*: Kara Bom industry (cultural horizon 5 and 6). (modified from Derevianko 2010a)

edge. Along with clear Mousterian tools, a few typologically distinct Levallois points are also present. The share of denticulate tools is not great (12.3 %), while the value of the denticulate, notched-and beak-shaped tool index is twice as high. The share of Upper Paleolithic tools is the highest within the collection (29.7 %). This category includes such typologically distinct types as end-scraper, burins, borers and backed blades. Stratum 11 also yielded a few foliate bifaces. Also present were bone, shell, mammoth tusk and animal teeth (Derevianko 2010b).

Ust'-Karakol 1 site is located in the Anui river valley (51°22"N, 84°41"E). This site convincingly demonstrate the transition from the Middle to Upper Paleolithic, and the lithic complex from horizons 11–9 is comparable with stratum 11 at Denisova cave (Fig. 5.3: 1–26). A series of radiocarbon dates has been generated on charcoal and humid acids from fireplaces in strata 10 and 9c with results of 35,000 uncalibrated BP for the uppermost portion of stratum 10: 33,400 uncalibrated BP and 29,700 uncalibrated BP for stratum 9c (Derevianko 2010a).

Based on archaeological materials from Denisova cave and Ust'-Karakol 1 site, Anatoli Derevianko recognize that the development of a Middle Paleolithic industry into an Upper Paleolithic one on the basis of the Levallois facies. The process of transition seems to have started approximate 60,000–50,000 BP and ended with the formation of an Upper Paleolithic industry approximate 50,000–40,000 BP. or possibly earlier (Derevianko 2010b).

The complex from habitation horizons 5 and 6 in the Kara-Bom site differs considerably from the early Upper Paleolithic complex of Ust'-Karakol 1 in terms of major features of both primary and secondary reduction. Kara-Bom has yielded mainly parallel cores dominated by narrow faced forms, from which long and narrow blades were removed (Fig. 5.3: 27–44). Tools are mostly made on blades. For instance, the share of tools is 19.5 % of the total number of tools from horizon6, while the share of tools on blades in 70.6 % and that of tools on pointed flakes is 6.9 %. Tools were mostly fashioned on thin blades and consist of end-scrapers, multi-facetted burins, points, and blade-knives. The share of various retouched notched denticulate tools is also considerable. Available radiocarbon dates place horizons 5 and 6 at 43,000 uncalibrated BP for. Also from horizon 5 and 6 found symbolic behaviour such as portable ornaments and ochre fragments (Derevianko et al. 1998).

The lithic complex from Okladnikov cave (51°44"N, 84°02"E) is quite unique, in considering the Middle to Upper Paleolithic transition in the Altai. A distinct feature of the industry from Okladnikov Cave differs principally from all other Middle Paleolithic assemblages of the Altai: it looks more Mousteroid and contains a large number of convergent scrapers of the déjeté type. Layer 7, 6, and 3 to 1 contain cultural remains. This site has been uranium dates and radiocarbon dated from cultural-bearing horizons. Uranium dates of 44,600 ± 3,300 and 44,800 ± 4,000 BP generated on samples from layer 7 in gallery 1 (Derevianko 2010a). Radiocarbon dates on bone samples from layer 3 is 47,700 to 16,210 uncalibrated BP. Dating human adult human bone is 24,260 ± 180 uncalibrated BP. The dates on a juvenile bone fall within the range of 29,990 ± 500 to 37,800 ± 450 uncalibrated BP. 40,000–32,000 uncalibrated BP, corresponding to 47,000–35,000 cal BP. Anatoli Derevianko is assumed the time range of the lithic complex falls within the range of 45–40 ka BP (Derevianko 2010a). By that time, the Karakol and Kara-Bom variants of the early Upper Paleolithic culture had already formed in the Altai, whereas the Okladnikov industry was dominated by Mousteroid artefacts with a minor proportion of Upper Paleolithic tools.

In 2007, S.V. Markin discovered the Chagyrskaya Cave in southwestern Altai. Excavations continued in 2008 and 2009. The Chagyrskaya lithic assemblage is analogous to the Okladnikov industry both in primary reduction strategy and typological characteristics. For a long time, it was hard to find an explanation for the phenomenon of the Okladnikov Paleolithic complex. Whereas the Upper Paleolithic culture had already formed over a large part of the Altai territory, synchronous Okladnikov and Chagyrskaya complexes possessed a Mousteriod character.

Anatoli Derevianko has tried to explain this phenomenon of the Middle to Upper Paleolithic transition in the Altai, presenting the following hypothesis (Derevianko 2010a). In Southern Siberia, the process of transition seems to have started approximate 60,000 BP, in the course of gradual development of the Middle Paleolithic industry in the Altai, with an increasing the proportion of the Upper Paleolithic tools including end-scrapers, burins, and implements on blades. Narrow-face, wedge-shaped, and other cores for blades appeared, while the number of Levallois and radial cores diminished. At approximately 50,000–40,000 BP, during the Middle to Upper Paleolithic transitional period, two types of the early Upper Paleolithic industry were formed: the Kara-Bom and Karakol industries.

The common feature of the Kara-Bom and Karakol trends is that the assemblage 50,000–40,000 years old still retained elements of the Levallois and radial reduction strategies. The relevant toolkits include various forms of side-scrapers and other tools that are typical of the final Middle Paleolithic. Simultaneously, during 45,000–40,000 BP, another Mousteroid industry existed in the Altai: Sibiryachikha. This industry was entirely different in terms of technology and typology (Derevianko 2010a).

In summary, studies of cave and open-sir site in the Altai provide evidence of the formation process of two Upper Paleolithic industries: the Kara-Bon blade-based industry and Karakol industry based on blades and micro-blades. Both industries developed from a common local Middle Paleolithic. Furthermore, the distinctive feature of the Middle to Upper Paleolithic transition in the Altai is that the Mousteriod industry of Sibiryachikha, independently, existed within the same region, when two of the early Upper Paleolithic industries had already appeared.

5.4 The Middle to Upper Paleolithic Transition in the Lake Baikal Region

5.4.1 The Variability of the Middle Paleolithic in the Lake Baikal Region

Archaeological materials around Lake Baikal show both similar and different features to those already described. The Middle Paleolithic spread to both north and south across Lake Baikal. However, there are differences in the composition of tool kits and in primary reduction technology.

The Middle Paleolithic in the southern Baikal Siberia or "Zabaikal" (Trans-Baikal), has characteristics in common with the complexes of Mongolian plateau. These include the typical Levallois technological tradition in both the reduction strategy and the categories of retouched tools. Such features, might suggest a degree of cultural continuity with Central Asia and the Near East.

In the Trans-Baikal, archaeological sites that have been related with the Middle Paleolithic include Iren-Khada 1, layers 4–6 from Khotyk, Khenger-tyn 2, Khenger-Tyn rock-shelter, Khngerkte workshop and others (Bazalov 2011). Layers 5 and 6 at Khotyk (52°14"N, 109°50"E) have revealed geologically dated to 70,000–60,000 and 100,000–80,000 BP by the RTL dating method. Archaeological sites around of Khengerkte mountain (52°20"N, 109°49"E) found typical Levallois cores, Levallois points, various types of scrapers on flake, and denticulate tools. Similar lithic complexes of those of "Zabaikal" are found in the Art-Bogdo, region of the Mongolian plateau.

On the other hand, a bifacial reduction strategy has also been recorded at the Lower Paleolithic sites in the Angara river basin, in the northern Baikal Siberia or "Pribaikal" (Cis-Baikal). The lithic complex made on quartzite, has been found exposed on high terrace surfaces on the right bank of the Angara river and on the banks of the Bratsk reservoir. Similar lithic industries have also been reported from redeposited context in the lowermost portion of the MIS4 sediment (Medvedev 1998).

According to the relative stratigraphical position of these artefacts and the condition of Aeolian abrasion apparent on lithic surfaces, these complexes cannot be younger than MIS6. These archaeological sites includes the Tarakhaj-Igetej sites complex(53°34"N, 103°26"E). This includes flat discoidal cores, Levallois cores, *déjeté,* points and skleblos on massive flakes, and chopper/chopping tools.

The Middle Paleolithic complex in the Angara basin may be classified into two traditions: Igitej-Tarakhai and Olonsk. The Tarakhai group comprises industries with a well-developed pebble tool tradition. Primary reduction is based on the "citron" flaking method and chopper/chopping tools constitute a considerable proportion of the tool kit. The Olonsk group reflects a degree of similarity with late Acheulian industries. This group is characterized by bifacial radial flaked core-like implements, pebble tools, and micro-bifaces (Medvedev 1998; Shunikov 2005).

5.4.2 EUP Industries in the Lake Baikal Region

A relatively large number of sites identified as the early Upper Paleolithic in the Baikal region including Tolbaka, Kamenka, Pozvonkaya, Khotyk on the south side of Lake Baikal (Trans-Baikal), and Igeteiski-Log, Bol'shoj-Narin 1, Alembovski, Makarovo 4 in Cis-Baikal on the north side of Lake. Additionally, in recent year, new archaeological sites related with this transition period, such as Gerasimov, Sedova, Shapova have been discovered in the vicinity of Irkutsk city (Larichev et al. 2009).

One of the distinct sites in the Cis-Baikal is the Makarovo 4 site (54°00"N, 105°47"E) located in the upper Lena basin. The lithic complex from Makarovo 4 is characterized by parallel and sub-parallel reduction from flat-faced cores. The tool kit is rich and includes side-scrapers of various types, end-scrapers, transversal burins, knives, and borers (Fig. 5.4: 7–15). A distinctive features of this complex is a set of leaf-shaped points made on long spalls with bifacially flaked bases (Fig. 5.4: 7–8)(Aksenov and Shunikov 1978). Similar points have been found in complexes from the Kara-Bom industry. Makarovo 4 site radiocarbon dated to more than 38,000 and 39,000 uncalibrated BP. (Goeble and Aksenov 1995). However, based on geoarchaeological perspective and aeolian corrosion of the artefacts, German Medvedev and Mikhael Aksenov have argued in favour of an even earlier dated for Makarovo 4 site (Aksenov et al. 1987). A similar lithic complex to that of Makarovo 4 site is found at Alemvovski (52°19"N, 104°19"E) (Semin et al. 1990).

On the other hand, Bol'shoj-Narin 1(Fig. 5.4: 6) and Shapova sites have been yielded Mousteriod complexes. Primary reduction strategy of the complex from Shapova (52°17"N, 104°18"E) complex is based on the flake reduction strategy, not on the blade reduction strategy, and the dominant core types are discoidal and chopping/chopper. The tool kit contains points made on flake, *déjeté,* skleblos on massive flakes, and various types of side-scrapers and denticulate tools (Fig. 5.4: 1–5). This site has been radiocarbon dated to 39,900 ± 1,295 uncalibrated BP (Kozyrev and Slagoda 2007).

In the southern Baikal region, sites such as Tolbaga (layer 4), Varvarina Gora (layer 3), Kamenka A, Khotyk (layer 3) and Pozvonkaya have yielded complexes chronologically and technologically closed related to the Kara-Bom industry. The complex from Pozvonkaya site (52°14"N, 109°50"E) is dated to 43,000 uncalibrated BP (Tashak 2003).

The primary reduction technology of eastern Baikal was based on parallel flaking of flat-face and proto-prismatic cores, and some narrow face flaking. Blades were used as tool blanks. The tool kit includes points, burins, end-scraper, borers, and retouched blades. The characteristics of these complexes include the presence of symbolic items such as personal ornaments and small beads, as well as a unique bone figurine of a bear head (Konstantinov et al. 1983).

In summary, the process of transition in the Baikal region also began the process of transition seems to have started approximately 45,000–35,000 BP. However, this process is not a simple one, with a great diversity of Middle Paleolithic complexes evident in the Baikal region. Some of scholars have been suggested that early Upper Paleolithic people migrated into this region from the Altai, around 60,000–50,000 BP (Derevianko 2010b). On the other hand, Mousteroid complexes existed in the same period.

5.5 Concluding Remarks

In Siberia, several fossil remains have been found, especially from the Altai caves. As a result, it is now clear that Neanderthals, Denisovans and modern human once occupied the region. Ancient DNA from Denisovans suggests that their home range once stretched far beyond the Altai, into

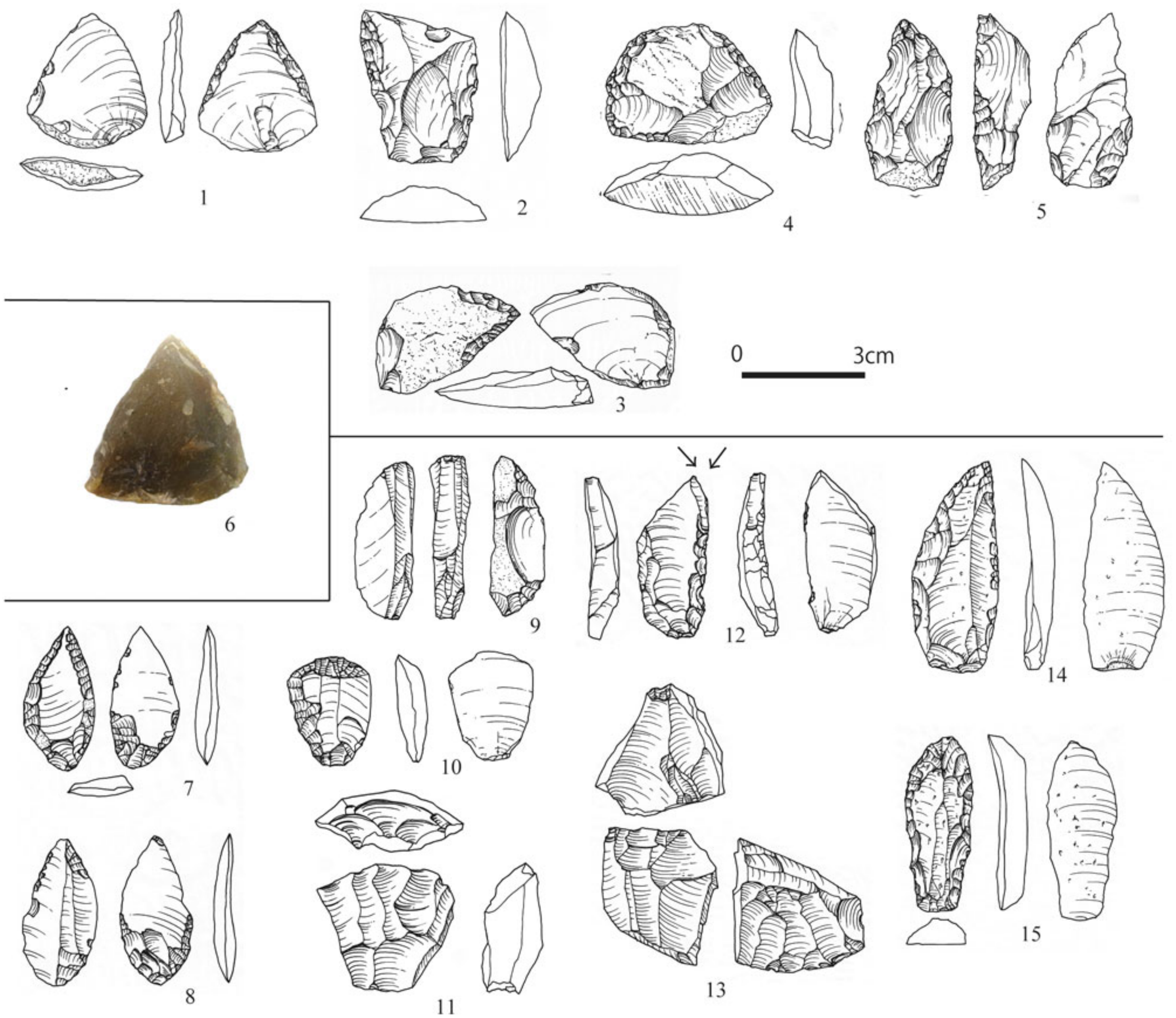


Fig. 5.4 Middle to Upper Paleolithic transition industry in the Lake Baikal region. *1–5*: Shapova, *6*: Bal'shoj Narin 1, *7–15*: Makarovo 4. (*1–5*: modified from Kozyrev and Slagoda 2007; *6–15*: modified from Medvedev 1998)

eastern and southeast Asia. A consideration of the Middle to Upper Paleolithic transition in Siberia, indicates a more complex aspects. As concluding remarks, I would like to summarize some of these aspects of the Middle to Upper Paleolithic in Siberia.

5.5.1 Technological Diversity in the Siberian Middle Paleolithic

Middle Paleolithic sites in Siberia have yielded a variety of techno-typological complexes. For instance, in the Altai, the earliest Middle Paleolithic industry from Denisova cave demonstrate Levallois features in primary reduction and in the presence of various types of side-scrapers and notched-denticulate tools in the tool kit. The middle of stage of development of Middle Paleolithic industries have been classified into two groups: Mousterian and Levallois. The final stage of development of the Middle Paleolithic industry is illustrated by Mousteriod industry of Sibiryachikha.

The Middle Paleolithic industry in the Urals divided two migration stages. The first of the Middle Paleolithic groups refer to the eastern Micoquian industry with similar type of knives to those of the “Keilmesser group.” Another one is related to the Szletsian industry. In this region, the various techno-complexes is represented the repeated human migration and colonization of the Arctic region from Eastern Europe.

In the Baikal region, the presence of various Middle Paleolithic industries can also be seen. Middle Paleolithic complexes on the southern side of Lake Baikal are widespread and reflect a Mousterian industry represented by the typical Levalliois reduction strategy and characteristics retouched tools. On the other hand, a bifacial reduction strategy has been reported for Middle Paleolithic complexes from the northern side of Lake Baikal. The Middle Paleolithic in the Angara basin also represents the Levallois technological tradition, however a typical Levallois reduction strategy is not dominate in the primary reduction from these complexes.

5.5.2 Highly Flexible Technology and Tools, Which Adapted with Environmental Changes

The Middle to Upper Paleolithic transition shares development trend characterized by the standardization of blade reduction strategy and by stylized retouched tools on blades. Within Siberia the closest similarity is seen in blade reduction techniques such as the Kara-Bom, Karakol, and Makarovo industries in this stage.

The characteristics of this parallel reduction strategy and blade production including micro-blade production from narrow-faced cores, emphasized the advantages of this techno-complex in environmental adaptation. The wide distribution of the high blade production using parallel reduction strategy reflects strong human intentions. During the unstable climate condition of MIS3, the flexible technological system adapted with along with a high mobile life-style were selected in order to secure resources.

This category of highly flexible technology also could include the bone/antler tools. These new materials were well suited in term of their portability, technological efficiency, and tool curation as well as the climate-environmental conditions of Siberia.

References

Aksenov M, Berdnikov M, Medvedev G, Perzhakov S, Fedorenko A (1987) Morfologia i arkheologicheskii vozrast kamennego inventaria “Makarovskogo paleoliticheskogo plasta”. In: Medvedev G (ed) Problemy antropologii i arkheologii kamennogo veka Evrazii. Izdatel'stovo Irkutsk gos. Universitet, Irkutsk, pp 26–30 (in Russian)

Aksenov M, Shunikov M (1978) Novoe v paleolite verkhnei Leny: (predvarit. dannye ob issed. Makarovo IV). In Medvedev (ed) Drevnyaya istoriya narodov yugo Vostochnoi Sibiri. vyp 4, Irkutsk gos. Universitet, Irkutsk, pp 31–55 (in Russian)

Bazalov B (ed) (2011) Istoliya Buryatii, tom 1. Izdatel'stvo BNTS SO RAN, Ulan-Ude (in Russian)

Chlachula J (2010) Environmental context of Pleistocene peopling of the central Urals. Quat Int 220:47–63

Derevianko A (2010a) Three scenarios of the Middle to Upper Paleolithic transition. Scenario 1: the Middle to Upper Paleolithic transition in northeast Asia. Archaeol Ethnol Anthropol Eurasia 38(3):2–32

Derevianko A (2010b) The Middle to Upper Paleolithic transition in southern Siberia and Mongolia. In: Boyle K, Gamble C, Bar-Yosef O (eds) The Upper Paleolithic revolution in global perspective. McDonald Institute for Archaeological Research, Cambridge, pp 103–113

Derevianko A, Shunikov M (2005) The Karama Lower Paleolithic site in the Altai: initial results. Archaeol Ethnol Anthropol Eurasia 3(23):52–69

Derevianko A, Petrin V, Rybin E, Chevalkov L (1998) Paleolicheskie kompleksy Stratifirovannoj Chasti Stoyanki Kara-Bom. Izdatel'stvo IAE SO RAN, Novosibirsk (in Russian)

Gibbons A (2011) Who were the Denisovans? Science 333:1084–1087

Goeble T, Aksenov M (1995) Accelerator radiocarbon dating of the initial Upper Paleolithic in southeast Siberia. Antiquity 69: 349–357

Guslitser B, Pavlov P (1993) Man and nature in northeastern Europe in the Middle and Late Pleistocene. In: Soffer O, Praslov N (eds) From Kostenki to Clovis. Plenum, London, pp 113–123

Konstantinov M, Sumarokov V, Filippov A, Ermalova N (1983) Drevneishaia skulpturra Sibiri. KSIA 173:78–81 (in Russian)

Kozyrev A, Slagoda E (2007) <Shchapova>: Novye geoarkhologicheskoe mestonakhozhdenie verkhnego plejstotsena v g. Irkutske. In: Medvedev G (ed) Antropologen: paleoantropologiya, geoarkheologiya, etnologiya Azii. Izdatel'stvo Ottisk, Irkutsk, pp 81–89

Kozlowski J (2010) The Middle to Upper Paleolithic transition north of the continental divide: between England and Russian plain. In: Boyle K, Gamble C, Bar-Yosef O (eds) The Upper Paleolithic revolution in global perspective. McDonald Institute for Archaeological Research, Cambridge, pp 123–135

Krause J, Fu Q, Good J, Viola B, Shunkov M, Derevianko D, Pääbo S (2010) The complate mithchondrial DNA genome of an unknown hominin from southern Siberia. Nature 464:894–897

Larichev V, Lipnina E, Medvedev G, Kogaj S (2009) Angarskij Paelolit: U istokov <khdozhestvenogo tvorchetva> rannykh *Homo sapiens* Vostochnoj Sibiri I nachalo obreteniya imya protonauchnykh znanij o prirode. In: Medvedev G (ed) Vuzoskaya nauchnaya arkheologiya I etonologiya Severnoj Azii. Irkutskaya shkola 1918–1937. Amtera Irkutsk, pp 246–264 (in Russian)

Medvedev G (1998) The Lower Palelithic of eastern Siberia. In: Derevianko AP (ed) The Paleolithic of Siberia. University of Illinois Press, Chicago, pp 27–34

Meignen L, Delagnes A, Bourgnon L (2009) Patterns of lithic material procurement and transformation during the Middle Paleolithic in western Europe. In: Adams B, Blades B (eds) Lithic materials and Paleolithic societies. Blackwell, West Susex, pp 15–21

Pavlov P, Roebrock W, Svendsen J (2004) The Pleistocene colonization of northeastern Europe: a report on recent research. J Hum Evol 47:3–17

Pavlov P (2009) Paleolit Cevero-Vostoka Evropy. Dissertatsiya na soiskanie uchnoj stepeni doktora istoricheskikh nauk. Institu Iazyka, Literatury I istorii Komi nauchnogo tsentra UO RAN, Syktyvkar (in Russian)

Reich D, Green R, Kircher M, Krause J, Patterson N, Durand E, Viola B, Briggs A, Stenzel U, Johnson P, Maricic T, Good J, Marques-Bonet T, Alkan C, Fu Q, Mallick S, Li H, Meyer M, Eichler E, Stoneking M, Richards M, Talamo S, Shunkov M, Derevianko A, Hublin J, Kelso J, Slatkin M, Paabo S (2010) Genetic history of an archaic hominin group from Denisova Cave in Siberia. Nature 468:1053–1060

Semin M, Shekovaya S, Chebotarev A (1990) Novye paleoliticheskoe mestonakhozhdenie v g. Irkutskt (imeni I.V. Arembovsogo).

In: Medvedev G (ed) Paleoetnologiya Sibiri. Izdatel'stvo Irkutsk gos. Universitet, Irkutsk, pp 114–115 (in Russian)

Shunikov N (2005) The characteristics of the Altai (Russia) Middle Paleolithic in regional context. Indo Pacific Prehist Assoc Bull 25:69–77

Svendsen J, Heggen H, Hufthammer A, Mangerud J, Pavlov P, Roebroeks W (2010) Geo-archaeological investigations of Paleolithic sites along the Ural Mountains – on the northern presence of humans during the last Ice Age. Quat Sci Rev 29:3138–3156

Svendsen J, Pavlov P (2003) Mamontovaya Kurya: an enigmatic nearly 40000 years old Paleolithic site in the Russian Arctic. In: Zilhão J, D'Errico F (eds) The chronology of the Aurignacian and of the transitional technocomplexes: dating, stratigraphies, cultural implications. Instituto Português de Arqueollogia, Lisboa, pp 109–120

Tashak V (2003) Hearths at the Pozvonkaya Paleolithic site: evidence suggestive of the spirituality of early populations of the Trans-Baikal region. Archaeol Ethnol Anthropol Eurasia 3(15):70–78

6 Cultural Transmission, Institutional Continuity and the Persistence of the Mousterian

Steven L. Kuhn

Abstract

Mousterian or Eurasian Middle Paleolithic material culture represents an extremely successful set of hominin adaptations. Mousterian technologies were used for more than 200,000 years by groups living in diverse habitats through several glacial/interglacial cycles. Yet they also disappeared surprisingly rapidly following the expansion of anatomically modern *Homo sapiens* into Eurasia. In fact, the same factors that underpinned the apparent success of the Mousterian technologies and culture may have hastened their eventual disappearance. Middle Paleolithic populations, though widespread, were small and fragmented into numerous local demes. Middle Paleolithic foragers fed at a high trophic level, which would have facilitated expansion into empty habitats but also would have kept absolute densities low. These demographic conditions help explain the apparent continuity in Mousterian culture across great expanses of space and time. Small, fragmented populations limit the rates at which innovations appear and spread. Unstable populations also inhibit the development of robust social networks and other cultural institutions that can store latent cultural information. But it is difficult for dispersed, fragmented populations to resist invasion. Any cognitive or cultural characteristics which led to greater continuity in early *Homo sapiens* populations and cultural institutions would have helped them to disrupt the already fragile social fabrics of Middle Paleolithic populations, and to establish a permanent presence in Eurasia.

Keywords

Change • Cultural transmission • Demography • Mousterian • Stasis

6.1 Introduction

Explanations for changes in Paleolithic behavior such as lithic technology have become increasingly focused on evolutionary processes. Most often, evolutionary explanations unite biological and behavioral change into simple adaptive equations: an external stimulus such as climate change results in a biological response, which in turn is manifest as changes in behavior. Sometimes the biological component is skipped entirely and behavioral evolution is seen as a direct response to environmental change. These scenarios lead us to expect that the appearance of a well-developed physical, cognitive, or cultural capacity should coincide with its full expression. The rational is simple and compelling: only strong selection would cause a major change in hominin anatomy or behavior so why would a capacity evolve except to be used?

This sort of linear conceptual model is a reasonable first approximation for evolutionary dynamics in the past. It also serves well in broad-brush narratives of long-term evolutionary change. But as one looks more closely and as the corpus

S.L. Kuhn (✉)
School of Anthropology, University of Arizona, Tucson, AZ 85721-0030, USA
e-mail: skuhn@email.arizona.edu

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_6,

of available data becomes richer, simple adaptive models begin to show their weaknesses. Behavioral and anatomical changes associated with the dispersal of *Homo sapiens* into Eurasia and the eventual disappearance of Neanderthals, the main focus of this book and the larger project it represents, illustrate this dilemma clearly. Neanderthals and *Homo sapiens* evolved equally large brains. Yet instances of supposedly complex, creative behaviors such as decorative art or personal ornaments, as well as innovations in technology, are much more common among the latter than the former. In fact, it is increasingly clear that Neandethals were capable of many of the same kinds of sophisticated strategies that have been identified as constituting "Modern Human Behavior," (see Chap. 3) but used them less frequently than contemporaneous late Pleistocene hominins in Africa. This leads us to an apparent paradox "Why evolve a big brain if it is not used for 'modern' thinking." One potential answer is that Neanderthals had evolved to use modes of thought as complex as, but different from, *Homo sapiens* (e.g., Mithen 1996, 2005, 2013; Wynn and Coolidge 2011). Another response, and the one that will be explored in this paper, is that we are dealing with a record not of capacities but of tendencies, so what we really need to ask is what might lead similarly-capable hominins to behave in such different ways over long periods of time (Kuhn and Stiner 2001; Shea 2011).

Weaknesses with simple adaptive explanations are similarly highlighted by the ways many novel behavioral traits stutter into existence during the Upper Pleistocene in Eurasia and southern Africa. It now appears that the precocious cultural developments of the Howiesons Poort and Stillbay industries of the South African late Middle Stone Age were limited to relatively narrow windows of time, and that many traits subsequently disappeared for tens of thousands of years, only to re-appear in the Late Stone Age (Jacobs and Roberts 2008; Jacobs et al. 2008; but see Brown et al. 2012). This scenario makes little sense if we assume that the appearance of a behavior coincides with the evolution of the capacity for that behavior. Simple adaptive models lead us to expect an orderly and non-reversible accumulation of cultural developments. Instead, supposedly advanced and presumably advantageous behaviors appear early and disappear, sometimes more than once: sometimes these inventions spread, but often they do not. The first reactions to these emerging patterns were to attribute anomalies to gaps in the record or poorly-controlled stratigraphy. As data have accumulated it now appears that the empirical findings are robust. The none-too-surprising implication of these observations is that the expression of particular traits is not simply a consequence of innate capacity but is strongly dependent on immediate conditions as well as prior states.

Fields such as biology and paleontology have faced similar crises with the sufficiency of simple adaptive models. Their response has been to develop new models of evolutionary change coupling natural selection to phenotypic plasticity and development ("evo-devo"), and to examine non-linear relationships between organisms and the selective context (complexity science, niche construction). Paleoanthropology is following along, a few decades behind as usual. Most recently Paleoanthropologists have turned to models combining demographic structure and cultural transmission with biological and cognitive evolution in order to explain the historical patterns with which they are faced. I will adopt a similar standpoint in this paper explain another paradox, namely why Neanderthal culture lasted so long and why it disappeared so suddenly.

The Middle Paleolithic (MP), most commonly associated with Neanderthals, was extraordinarily widespread and persistent. MP artifact assemblages were made, in one form or another, for more than 200,000 years in places as far removed as southern Iberia and central Siberia. These technologies also persisted though several glacial cycles with relatively little evidence for *cumulative* technological change. Whatever Middle Paleolithic hominins were doing, however their cultural adaptations were organized, they were certainly successful in a biogeographic sense. Yet within a few thousand years this persistent cultural pattern disappeared more or less completely from most of Eurasia, replaced by a series of often very different material cultural patterns defining the early Upper Paleolithic. It is commonly assumed that this sudden demise must be due to a catastrophic event or series of them, whether volcanic eruptions, Heinrich events, or the arrival of the Aurignacians. I will argue is that the same factors that underpinned the apparent success of the Mousterian technologies and culture may have hastened their eventual disappearance. More specifically, distinctive energetic regimes, small populations and small resident groups led to persistent material culture, but also to easily-disrupted lines of cultural transmission.

6.2 Energetics, Foraging and Demography in the Middle Paleolithic

The discussion begins with the energetics of MP hominins, mainly Neanderthals, a topic that has received much attention (e.g., Aiello and Wheeler 2003; Churchill 2006; Hockett and Haws 2005; Sorensen and Leonard 2001; Snodgrass and Leonard 2009; Steegman et al. 2002; Verpoorte 2006). Evidence coming from studies of prey choice and foraging, estimated energy demands of MP hominins, and patterns of raw material exploitation and transport combine to indicate that Middle Paleolithic hominins lived at low population densities compared even to recent foraging populations in similar environments, and that these sparse populations were partitioned into very small local groups.

Middle Palelithic groups were effective and efficient hunters of large game. In virtually every environment and climate interval, MP archaeofaunal collections are dominated by the bones of large terrestrial herbivores, ranging in size from mammoths to gazelles (reviewed in Gaudzinski-Windheuser and Kindler 2012; Gaudzinski-Windheuser and Niven 2009; Gaudzinski-Windheuser and Roebroeks 2011; Kuhn and Stiner 2006; Stiner et al. 2009; Stiner and Kuhn 2008). This particular patterns of prey choice indicate a persistent focus on the "highest ranked" foods, those yielding the greatest return in food value relative to time invested in pursuit and processing (reviwed by Stiner and Munro 2002). Stable isotope evidence also identifies Neanderthals at least as highly carnivorous, top predators (Bocherens and Drucker 2003; Bocherens et al. 2005; Richards et al. 2000, 2001) although it is important to emphasize that the isotope data pertain only to sources of protein in the diet.

It would be a mistake to characterize Middle Paleolithic hominins as completely carnivorous. There are both theoretical and empirical reasons to believe that they consumed significant quantities of other kinds of resources, including plants of various sorts. Emerging evidence suggests that some individuals at least ate a wide range of foods over their lifetimes (e.g., Barton et al. 1999; Henry et al. 2010; Lev et al. 2005). What the data on plant foods cannot tell us at present is how important these resources were—the evidence cannot be translated into the same kinds of quantitative units as the faunal remains. However, cross-cultural studies do show that when recent foragers were dependent on plant foods as a principal staple they inevitably used elaborate processes to grind or pulverize them before cooking in order to extract the maximum nutritive yield (Keeley 1995; Wright 1994). The fact that seed grinding equipment was never a consistent component of MP assemblages anywhere in its distribution suggest that vegetable foods were never the main source of nutrition, even in the most southerly part of the MP range.

Somewhat ironically, small game evidence also hints at the importance of large game in MP diets. Small animal remains in Middle Paleolthic faunal assemblages are nearly always limited to a few easily-collected taxa, principally tortoises and littoral mollusks where available. Except for a few unusual cases (e.g., Blasco and Fernández Peris 2012; Blasco et al. 2010) more abundant and fecund small animals such as lagomorphs and birds were ignored (Stiner and Kuhn 2008; Stiner et al. 2000; Stiner nd). Given their comparatively high energetic returns (summarized in Kuhn and Stiner 2001) we would expect these fast reproducing small animals to be added to the diet before many plant foods. The fact that this did not often occur indicates that MP hominins were seldom driven to broaden their diets due to an insufficiency of high-ranked large game. Instead, short-term or seasonal shortages or biological needs for particular nutrients may have motivated MP hominins to forage for plants or difficult-to-catch small game.

Neanderthals, the main makers of the Middle Paleolithic, also supported high somatic energy demands compared to most living peoples. Evidence for this comes from analyses of body size and proportion (e.g., Sorensen and Leonard 2001; Snodgrass and Leonard 2009) as well as from a consideration of their likely activity patterns and environments in which they lived (Aiello and Wheeler 2003; Churchill 2006; Steegman et al. 2002). Estimates of daily caloric requirements vary, but there seems to be general agreement that Neanderthals required significantly larger amounts of energy on a daily basis than recent foragers did under normal conditions. Combined with the dietary evidence, the high caloric demands of Neanderthals make it plain that most MP populations had to have been sparsely distributed compared even with recent foragers in similar environments. Because of the inevitable entropic loss of energy moving up through the food chain, the biomass of terrestrial predators is inevitably much smaller than the biomass of the prey on which they depend. The higher per-capita energy demands of Neaderthal bodies would reduce even further the number of individuals that could be supported on a given patch of habitat. Middle Paleolithic humans must have been remarkably thin on the landscape.

Of course estimates of relative population sizes do not tell us how the small MP populations were partitioned, how large or small the co-resident homin groups were. Here patterns of movement in lithic raw materials provide some provocative evidence. Raw material catchments, the areas from which useful stones were collected and moved to or through sites, are not the same as foraging ranges, but they should scale together: the larger the area people habitually cover in the search of food, the larger the area from which they can easily collect raw materials. In all regions raw materials in Middle Paleolithic sites consistently come from smaller catchment areas than in later Upper Paleolithic sites in the same regions (Gamble 1999, p. 315; Feblot-Augustins 1997). The implication is that Middle Paleolithic hominins habitually foraged out shorter distances from sites than their Upper Paleolithic successors. Importantly, the radii for raw material collection do vary across environments, so that for all periods, sites in the cold continental interior of Europe tend to contain stones from more distant sources than sites in warmer, better watered areas (Gamble 1999, pp. 314–315; Feblot-Augustins 1997, 2009). This covariance between transport distances and environment shows that mobility did respond to ecological factors in a predictable way, lending credence to the idea that raw material movement does tract foraging patterns to a degree.

Taken altogether the anatomical and archaeological evidence point to extremely small group sizes among MP hominins. In recent humans there is a direct relationship between the sizes of resident groups, sizes of territories, and the degree of dependence on large terrestrial prey (Antón et al. 2002; Hamilton et al. 2007a, b; Kelly 1995). Dedicated terrestrial hunters require large amounts of land to support themselves, and groups must cover a large amount of ground to making a living. The heightened energetic demands of the Neanderthal body would have meant even more land was needed to feed a single individual. Yet the lithic raw material data point to comparatively small habitual foraging ranges from individual sites. The only way to shoehorn highly carnivorous, high-energy hominins into small territories is to divide them into very small groups. The hypothetical minimum group size of 25 individuals commonly cited for recent foragers may not have obtained in the Middle Paleolithic.

It should be noted that genetic studies also argue for small, highly partitioned populations among Neanderthals (e.g., Briggs et al. 2009; Dalén et al. 2012; Fabre et al. 2009; Lalueza-Fox et al. 2005) the only MP hominins for which large samples of ancient DNA are available. Despite the fact that they seem to agree the genetic, skeletal and archaeological data are not really comparable. There are no clear guidelines for translating effective populations size into census population size. The genetic evidence also speaks to partitioning at a sub-continental scale, demes much larger than a single residential group.

6.3 Demography, Cultural Transmission, and Persistence

A number of recent studies have explored relations between demography and macroscopic patterns of cultural transmission. They show that the sizes, densities and structures of ancient populations can influence the rates at which cultural innovations appear and spread, as well as the frequency with which novelties are lost. In so far as demography directly influences the appearance of variation and continuity in material culture, and the persistence of MP cultures may be attributable in whole or in part to the distribution of hominins on ancient landscapes.

Shennan's pioneering (2001) study used a modified version of Peck et al.'s (1997) simulation model to explore the effects of population size on mean fitness under conditions where culturally transmitted traits had direct fitness consequences. In this model "innovations" occur randomly: a novel behavior is as likely to result in decreased fitness as in a fitness increase. Shennan showed that for a range of parameter settings and cultural transmission patterns (vertical and oblique), the size of the effective population is directly correlated with average fitness. The explanation is fairly simple: innovations with high fitness values are more likely to arise and to be adopted by others in larger populations as a simply function of the number of transmission events. A similar argument has been made concerning rates of genetic evolution in humans since the Neolithic (Hawks et al. 2007). In a subsequent paper, Powell et al. (2009) use a more sophisticated model developed by Henrich (2004) to further explore this phenomenon. They conclude that demographic factors, including both density and inter group migration can directly influence the accumulation and maintenance of complex cultural skills. These skills in turn enhance the success of a population, creating a positive feedback situation (see also Richerson et al. 2009). At the same time, even beneficial sorts of cultural knowledge can disappear from very small populations due to chance factors (Henrich 2004).

Population stability can also contribute to long–term trajectories of change and diversification in cultural behavior, and periods of apparent behavioral stability, such as characterize much of the record prior to (and arguably after) the origins of *Homo sapiens* could be in part a function of especially fragile local populations. There are many reasons to suspect that hunter-gatherer populations, Middle Paleolithic ones in particular but later ones as well, underwent cycles of growth and decline, with periods of local extinction (Shennan and Edinborough 2007; Riede 2009). Premo and Kuhn (2010) used a spatially-explicit agent-based model to examine the effects of rates of extinction in local sub-populations on the appearance of culture change and diversification over the long term. One outcome is that increasing rates of local extinction depressed cumulative change, total diversity, and inter-group variation, even when overall meta-population sizes remained constant. The infilling of patches of habitable territory recently vacated by extinction of sub-demes can further serve to homogenize cultural behavior across the spatial dimension, enhancing the appearance of continuity.

Of course from the perspective of cultural transmission, population size depends on more than just the number of individuals living in a particular area. The effective sizes of cultural populations are also closely related to the interconnectedness of individuals and local groups within a meta-population (Shennan 2001, p. 12). In a regional meta-population of hominins that is partitioned into small local groups that have little or no contact with each other, the effective local population sizes for cultural (and reproductive) purposes are much smaller than the census population for the species. If on the other hand the local groups are connected with each other and novel ideas can travel among them then the effective population size can be as large as the census population. In other words, social networks, connections among individuals and groups, may have the same kinds of effects as total population sizes (see Powell et al. 2009; Premo 2012). Fragmentation of thinly distributed Middle Paleolithic populations into small, disconnected local groups could amplify the effects of overall population numbers.

There is some reason to expect that MP groups were not extensively connected, that individuals maintained comparatively fairly small networks. Hunter-gatherers often establish and maintain links with distant individuals through the exchange of goods, in the form of reciprocal gifting or trade partnerships (e.g., Burch 1991; Schweizer 1996; Wiessner 1982; Yengoyan 1979). Consequently, we might expect direct evidence of intra-group contacts in the Paleolithic in the form of long-distance movement of lithic raw materials and other goods. In the Middle Paleolithic at least such evidence is sparse. Occasional objects are found hundreds of kilometers from the source (e.g., Arrizabalaga 2009; Slimak and Giraud 2007) but these are extremely scarce and quite prosaic, certainly not robust evidence for well-developed exchange networks. The scarcity of items of personal ornamentation in the Middle Paleolithic (see Chap. 3) further re-enforces the impression of small social groups with little need for outwards expression of identity (Kuhn and Stiner 2007). Certainly Middle Paleolithic hominins must have maintained local social networks, but there is currently no basis for predicting larger-scale connections among more distant groups or individuals (Foley and Gamble 2009; Gamble 1999).

The broader message from these theoretical studies of cultural transmission and demographic factors is that the apparent continuity in the Middle Paleolithic could be a consequence in part of the demographic structures of hominin populations. Because novel inventions accumulate and disperse slowly in small, dispersed and highly fragmented populations, they can produce an appearance of great cultural continuity with little directional change. Stochastic loss of both ideas and small local sub-demes can result in innovations that seem to blink in and out of existence. Apparent continuity at a continental scale, as well as the repeated appearance of same technological themes across long spans of time can emerge from constant, small-scale re-arrangement of sub-populations on landscape. Limited diversification of social roles produces little sustained pressure to recruit durable material culture into social interactions, to express identity through dress, artifact styles, etc. This further constrains variation in artifact form.

In addition to keeping populations small, flexible subsistence economies focused on large game would have provided provide strong impetus and potential to disperse into unoccupied territory. Populations of many high-ranked terrestrial prey animals are very sensitive to over-exploitation. The typical responses to such “resource depression” are either to move to a place where game is still plentiful or to broaden the diet (Broughton 1999; Nagoka 2002, p. 423). Because the ethology of large animals is fairly constant across space effective hunters can also easily transport their skills into new areas, making them effective colonizers (Kelly and Todd 1988). At the same time, small populations of hunters focusing their efforts on high-ranked game would lead to fragile local demes. Thus Middle Paleolithic hominins may have been good at colonizing territory as it was opened up by retreating glaciers or extinction of local group, but not so effective at holding on to it. Such thinly distributed, demographically fragile populations such as are hypothesized for the Middle Paleolithic are easily invaded. And once invaded, the already brittle lines of cultural transmission are quickly interrupted.

In the scenario outlined here we need not hypothesize that the invading population possessed a massive and widely-expressed cognitive or technological advantage. All that would be needed was slight edge in terms of population sizes or continuity of cultural lineages. I am not dismissing the potential for fundamental cognitive differences between MP and UP populations, but the point is that they are not strictly necessary. If invading *Homo sapiens* were already able to sustain slightly larger and more stable populations they could have held onto territory better than local MP hominins. The marginal demographic advantage could have come from division of labor and more diversified foraging strategies (Kuhn and Stiner 2006) or from improved technologies of food procurement such as hunting weapons (Shea and Sisk 2010). The presence of ornaments in south African MSA sites (d'Errico et al. 2005, 2008) and evidence for long-distance transfers of raw material the east African MSA (McBrearty and Brooks 2000; Merrick and Brown 1984; Merrick et al. 1994; Negash and Shackley 2006; Wilkins 2010) indicate that Upper Pleistocene African humans were already engaged in active social networking (Wilkins 2010). This could have provided a demographic advantage as beneficial innovations spread more quickly, enabling faster and more sustained population growth. Social networks may also have helped redistribute people according to the availability of resources, one way recent foragers used their networks of social connections.

Population size and structure may have a strong mechanistic influence on continuity of cultural transmission but there are possibilities for non-linear effects as well. Changes in the fidelity of transmission could by themselves produce saltational patterns in accumulation of culture, independent of ability to store or process information (Andersson 2011; Lewis and Laland 2012). Conventions of learning and apprenticeship, rites of passage, formal custodianships of specialized knowledge, and other social institutions help insure the effective transfer of valuable knowledge from one generation to the next, inhibiting the loss of cultural information. The same population factors that influenced the development and spread of innovations in material culture could have influenced the development and persistence of such social institutions. After all, these institutions must themselves be transmitted culturally, and they are just as durable or fragile as the populations they serve. The persistence or loss of social institutions related to teaching or learning would only enhance continuity or disruption in lines of cultural transmission.

6.4 Demography Alone Does Not Explain the Disappearance of the Neanderthals, but It Helps

Demography is a necessary part of any account of the replacement of Neanderthals by anatomically modern humans during the Upper Pleistocene. What after all is the supplanting of one population by another but a demographic event? Demographic models also have many advantages as explanations of long-term patterns of culture change across the Middle and Upper Paleolithic. They can account for a range of empirical patterns—from prey choice to trends in material culture change—without positing empirically inaccessible changes in cognitive physiology. In theory at least, demographic models are testable. Nonetheless, demographic models are far from complete explanations of evolutionary changes in behavior and anatomy during the Upper Pleistocene. Whereas demography may be necessary to explanations of the spread of *Homo sapiens* at the expense of the Neanderthals, it is by no means a sufficient explanation in itself.

At this point the main weakness with hypotheses about changes in the sizes and structures of Paleolithic populations is the lack of empirical verification. While plausible and consistent, these models are hard to test.

- Paleogenetic data, one source of estimates of effective populations sizes and structure, are available only for Neanderthals.
- Archaeological indicators of population numbers notoriously unreliable. They are also strongly affected by differences in research histories. This makes it difficult to compare population levels between the Middle and Upper Paleolithic, or between Europe and southern Africa.
- Foraging choices may be symptoms of population/resource balance, but they are also influenced by external factors affecting resource abundance. While prey species may change, the importance of large terrestrial herbivores in Middle Paleolithic diets is curiously insulated from glacial/interglacial cycles and major latitudinal gradients (Stiner nd; Stiner and Kuhn 2008). Still, we cannot rule out more subtle environmental influences.
- Expectations for the effects of population size on cultural diversity are scale-dependent: increased connectivity among groups could augment diversity at one spatial or temporal scale but restrict it at another (Kuhn 2012).
- Conventional approaches to documenting Paleolithic material culture are not amenable to systematic, quantitative analyses of diversity or cumulative change.
- Tests of models linking cultural diversity to population size in recent societies seem to work better for farmers than for hunter-gatherers (Collard et al. 2012)

Thinking about demography and cultural evolution also opens up a whole new suite of questions for which we currently lack answers. Perhaps the most compelling, and most difficult, is why MP hominins maintained this high-trophic feeding, low-density regime for so long? Clearly it was a difficult evolutionary transition for them to shift to another foraging regime. However, it was not due to some physical or mental (in) capacity to exploit other resources. Examples of Neanderthal forays into small game and seeds show that they *could* broaden their diets, but seldom did so for a prolonged period.

I do not have a definitive answer to this question, but I can propose the outline of one. Middle Paleolithic populations were successful and avid hunters of large terrestrial prey, strongly dependent in large game in a range of habitats. They were even able to practice selective hunting of prime-aged individuals. Yet they seem to have invested little in producing weaponry beyond simple hand-held or thrown spears (Shea 2006). Successful "low tech" hunting implies a high level of social cooperation. Rather than using sophisticated weapons to kill animals at a distance, MP hunters must have relied on other individuals to help them control the movements of prey, permitting them to take selected animals at close range. Thus, the success of Middle Paleolithic hunting was absolutely contingent on cooperation. And since groups were small, this meant that a large portion of the group, adults of both genders as well as physically capable children, would have had to participate in the hunt (Burke 2010; Kuhn and Stiner 2006; Stiner and Kuhn 2008).

Ultimately, large-scale changes in subsistence regimes are the products of countless individual decisions. A subsistence regime centered on cooperative hunting would have essentially locked individuals into certain roles. Decisions to pursue other options would have had negative consequences for both the individual and the group. For example, a person who decided to go off in search of small animals or roots would have been separated from the group, and from the first access to a successful kill. As non-participants they may have had fewer rights to the carcass. At the same time, decreasing the number of individuals available to cooperate in the hunt would have reduced the probability of success for the part of the group still pursuing large game, putting them at greater risk as well. Under such conditions, both individuals and groups would have been motivated to keep everyone doing the same thing. As a consequence of these constraints Middle Paleolithic hominins may this have been caught in a kind of "Malthusian trap" (Bocquet-Appel and Tuffreau 2009), keeping population levels low and limiting development and spread of novel forms of material culture. This is also an example of hominin niche construction, but one with a very different outcome from we know from later hunter-gatherers.

In closing I want to emphasize that by focusing this discussion on the sizes and structures of Paleolithic populations I am not denying the possibility of cognitive, neurological differences between Neanderthals and anatomically modern

Homo sapiens. Nor can we discount the potential influence of rates of innovation, inherent or culturally-supported levels of creativity, on the pace and pattern of culture change (see Chap. 12). I have assumed cognitive equivalence simply for the sake of argument. I emphasize demographic and social processes because they seem most accessible using archaeological data, and are at least potentially testable.

More importantly, demography and cognitive evolution are not independent. There are many reasons to believe that there is feedback between demography, group size and organization, and evolution of the human brain. The ways the human brain evolved, the ways it develops over the course of an individual's life-span, and the work it does on a day-to-day basis are inextricably linked to the social milieus in which people have lived. The widely discussed "social brain" hypothesis (Dunbar 1996), which needs no elaboration here, is an obvious example. The notion of the "extended mind" (Clark 2008; Clark and Chalmers 1998), the proposition that mind is a product of interactions between the individual brain and the external world of people and things, also implies that the expression of many cognitive capacities will be tied directly to the scale and richness of the social world: larger, more diverse societies should help scaffold bigger, more active minds. Finally, there is development, the dimension least thoroughly explored by Paleoanthropologists and others interested in human cognitive evolution. Assuming that the adult mind is partly if not largely the product of individual development, then the social context of child rearing, the sizes and compositions of groups that growing children contact regularly, the sorts of activities they experience on a regular basis, should have had important influence on the ways different cognitive capacities were actualized in the past. In this respect it is encouraging to see so much attention focused on child-rearing and learning in small scale societies by teams involved in the RNMH project.

Acknowledgements I want to thank Prof. Akazawa and Prof. Nishiaki for inviting me to participate in one of the most stimulating conferences I have had the opportunity to attend. Their vision in organizing the RNMH project is an example to us all. My thinking about the topics covered in this paper has been strongly influenced by interactions with colleagues including Jeff Brantingham, Mark Collard, Peter Hiscock, Charles Perreault, Luke Premo, Kim Sterelny, and Mary Stiner.

References

Aiello LC, Wheeler P (2003) Neanderthal thermoregulation and the glacial climate. In: van Andel T, Davies W (eds) Neanderthals and modern humans in the European landscape during the last glaciation. McDonald Institute Monographs in Archaeology, Cambridge, pp 147–166

Andersson C (2011) Paleolithic punctuations and equilibria: did retention rather than invention limit technological evolution? PaleoAnthro 2011:243–259

Antón S, Leonard WR, Robertson ML (2002) An ecomorphological model of the initial hominid dispersal from Africa. J Hum Evol 43:773–785

Arrizabalaga A (2009) The Middle to Upper paleolithic transition on the Basque crossroads: main sites, key issues. Mitt Ges Urgesch 18:39–70

Barton RNE, Currant A, Fernandez-Jalvo Y, Finlayson C, Goldberg P, Macphail R, Pettit P, Stringer C (1999) Gibraltar Neanderthals and results of recent excavations in Gorham's, Vanguard, and Ibex Caves. Antiq 73:13–24

Blasco R, Fernández Peris J (2012) A uniquely broad spectrum diet during the Middle Pleistocene at Bolomor Cave (Valencia, Spain). Quat Int 252:16–31

Blasco R, Fernández Peris J, Rosell J (2010) Several different strategies for obtaining animal resources in the late Middle Pleistocene: the case of level XII at Bolomor Cave (Valencia, Spain). Comptes Rendus Palevol 9(4):171–184

Bocherens H, Drucker DE (2003) Reconstructing Neanderthal diet from 120,000 to 30,000 BP using carbon and nitrogen stable isotopic abundances. In: Patou-Mathis M, Bocherens H (eds) Le rôle de l'envireonnement dans le comportements des chasseurs-cuillieurs préhistoriques, BAR international series 1105. British Archaeological Reports, Oxford, pp 1–8

Bocherens H, Drucker DG, Billiou D, Patou-Mathis M, Vandermeersch B (2005) Isotopic evidence for diet and subsistence pattern of the Saint-Césaire I Neanderthal: review and use of a multi-source mixing model. J Hum Evol 49:71–87

Bocquet-Appel JP, Tuffreau A (2009) Technological responses of Neanderthals to macroclimatic variations (240,000–40,000 BP). Hum Biol 81(2–3):287–307

Briggs AW, Good JM, Green RE, Krause J, Maricic T, Stenzel U et al (2009) Targeted retrieval and analysis of five Neanderthal m tDNA genomes. Science 325(5938):318–321

Broughton JM (1999) Resource depression and intensification during the Late Holocene San Francisco Bay: evidence from the emeryville shellmound. Ph.D. dissertation, Department of Anthropology, University of California, Berkeley

Brown KS, Marean CW, Jacobs Z, Schoville BJ, Oestmo S, Fisher EC, Bernatchez J, Karkanas P, Matthews T (2012) An early and enduring advanced technology originating 71,000 years ago in South Africa. Nature 491:590–593

Burch ES Jr (1991) Modes of exchange in north-west Alaska. In: Ingold T, Riches D, Woodburn J (eds) Hunters and gatherers, vol. 2: property, power, and ideology. Berg, Oxford, pp 95–109

Burke A (2010) Spatial abilities, cognition and the pattern of Neanderthal and modern human dispersals. Quat Int 247:230–235

Churchill SE (2006) Bioenergetic perspectives on Neanderthal thermoregulatory and activity budgets. In: Harvati K, Harrison T (eds) Neanderthals revisited: new approaches and perspectives. Springer, Dordecht, pp 113–134

Clark A (2008) Supersizing the mind: embodiment, action, and cognitive extension. Oxford University Press, New York

Clark A, Chalmers DJ (1998) The extended mind. Analysis 58:7–19

Collard M, Ruttle A, Buchanan B, O'Brien MJ (2012) Risk of resource failure and toolkit variation in small-scale farmers and herders. PLoS One 7(7):e40975. doi:10.1371/journal.pone.004097

Dalén L, Orlando L, Shapiro B, Brandström-Durling M, Quam R, Gilbert MTP, Díez Fernández-Lomana JC, Willerslev E, Arsuaga JL, Götherström A (2012) Partial genetic turnover in Neandertals: continuity in the East and population replacement in the West. Mol Biol Evol 29(8):1893–1897

d'Errico F, Henshilwood C, Vanhaeren M, van Niekerk K (2005) Nassarius kraussianus shell beads from Blombos Cave: evidence for symbolic behaviour in the Middle Stone Age. J Hum Evol 48(1):3

d'Errico F, Vanhaeren M, Wadley L (2008) Possible shell beads from the Middle Stone Age layers of Sibudu Cave, South Africa. J Archaeol Sci 35(10):2675–2685

Dunbar RIM (1996) Grooming, gossip, and the evolution of language. Harvard University Press, Cambridge

Fabre V, Condemi S, Degioanni A (2009) Genetic evidence of geographical groups among Neanderthals. PLoS One 4(4):e5151

Feblot-Augustins J (1997) La circulation des matières premières au Paleolithique. Vol. 1 et 2. ERAUL 75, Liège (in French)

Feblot-Augustins J (2009) Revisiting European Upper Palaeolithic raw material transfers: the demise of the cultural ecological paradigm? In: Adams B, Blades BS (eds) Lithic materials and Paleolithic societies. Wiley, New York, pp 25–46

Foley R, Gamble C (2009) The ecology of social transitions in human evolution. Philos Trans R Soc B 364:3267–3279

Gamble C (1999) Palaeolithic societies of Europe. Cambridge University Press, Cambridge

Gaudzinski-Windheuser S, Kindler L (2012) Research perspectives for the study of Neanderthal subsistence strategies based on the analysis of archaeozoological assemblages. Quat Int 247:59–68

Gaudzinski-Windheuser S, Niven L (2009) Hominid subsistence patterns during the Middle and Late Paleolithic in Northwestern Europe. In: Hublin JJ, Richards M (eds) Evolution of human diets: integrating approaches to the study of Palaeolithic subsistence. Max Planck Institute for Evolutionary Anthropology, Vertebrate paleobiology and paleoanthropology series, Germany subseries. Springer, Dordrecht, pp 99–111

Gaudzinski-Windheuser S, Roebroeks W (2011) On Neanderthal subsistence in last interglacial forested environments in Northern Europe. In: Conard N, Richter J (eds) Neanderthal lifeways, subsistence and technology. Springer, Dordrecht, pp 61–71

Hamilton MJ, Milne BT, Walker RS, Brown JH (2007a) Nonlinear scaling of space use in human hunter-gatherers. Proc Natl Acad Sci USA 104(11):4765–4769

Hamilton MJ, Milne BT, Walker RS, Burger O, Brown JH (2007b) The complex structure of hunter-gatherer social networks. Proc R Soc B 247(1622):2195–2202

Hawks J, Wang E, Cochran GM, Harpending H, Moyzis RK (2007) Recent acceleration of human adaptive evolution. Proc Natl Acad Sci USA 104:20753–20758

Henrich J (2004) Demography and cultural evolution: how adaptive cultural processes can produce maladaptive losses: the Tasmanian case. Am Antiq 69:197–214

Henry AG, Brooks AS, Piperno DR (2010) Microfossils in calculus demonstrate consumption of plants and cooked foods in Neanderthal diets (Shanidar III, Iraq; Spy I and II, Belgium). Proc Natl Acad Sci USA 108(2):486–491

Hockett B, Haws JA (2005) Nutritional ecology and the human demography of Neandertal extinction. Quat Int 137:21–34

Jacobs Z, Roberts RG (2008) Testing times: old and new chronologies for the Howiesons Poort and still Bay industries in environmental context. S Afr Archaeol Soc Goodwin Ser 10:9–34

Jacobs Z, Roberts RG, Galbraith RF, Deacon HJ, Grün R, Mackay A, Mitchell P, Vogelsang R, Wadley L (2008) Ages for the Middle Stone Age of southern Africa: implications for human behavior and dispersal. Science 322:733–735

Keeley L (1995) Protoagricultural practices among hunter-gatherers: a cross-cultural survey. In: Price TD, Gebauer AB (eds) Last hunters, first farmers. School of American Research, Santa Fe, pp 243–272

Kelly R (1995) The foraging spectrum: diversity in hunter-gatherer lifeways. Smithsonian Institution Press, Washington, DC

Kelly R, Todd LC (1988) Coming into the country: early Paleoindian hunting and mobility. Am Antiq 53(2):231–244

Kuhn S (2012) Emergent patterns of creativity and innovation in early technologies. In: Elias S (ed) Creativity, innovation and human evolution. Elsevier, Amsterdam, pp 69–87

Kuhn S, Stiner MC (2001) The antiquity of hunter-gatherers. In: Panter-Brick C, Layton RH, Rowley-Conwy PA (eds) Hunter-gatherers, an interdisciplinary perspective. Cambridge University Press, Cambridge, pp 99–142

Kuhn S, Stiner MC (2006) What's a mother to do? A hypothesis about the division of labor and modern human origins. Cur Anthro 47(6):953–980

Kuhn S, Stiner MC (2007) Body ornamentation as information technology: towards an understanding of the significance of early beads. In: Mellars P, Boyle K, Bar-Yosef O, Stringer C (eds) Rethinking the human revolution: new behavioural and biological and perspectives on the origins and dispersal of modern humans. MacDonald Institute of Archaeology, Cambridge, pp 45–54

Lalueza-Fox C, Sampietro ML, Caramelli D et al (2005) Neandertal evolutionary genetics: mitochondrial DNA data from the Iberian peninsula. Mol Biol Evol 22:1077–1081

Lev E, Kislev ME, Bar-Yosef O (2005) Mousterian vegetal food in Kebara Cave, Mt. Carmel. J Archaeol Sci 32:475–484

Lewis HM, Laland KN (2012) Transmission fidelity is the key to the build-up of cumulative culture. Philos Trans R Soc Lond B 367(1599): 2171–2180

McBrearty S, Brooks A (2000) The revolution that wasn't: a new interpretation of the origin of modern human behavior. J Hum Evol 39(5):453–563

Merrick HV, Brown FH (1984) Obsidian sources and patterns of source utilization in Kenya and northern Tanzania: some initial findings. Afr Archaeol Rev 2:129–152

Merrick HV, Brown FH, Nash W (1994) Use and movement of obsidian in the Early and Middle Stone Ages of Kenya and northern Tanzania. In: Childs ST (ed) Society, culture and technology in Africa, MASCA Research Papers in Science and Archaeology, vol 11. (Supplement), Philadelphia, pp 29–44

Mithen SJ (1996) The prehistory of the mind: a search for the origins of art, religion, and science. Thames and Hudson, London

Mithen SJ (2005) The singing Neanderthals: the origins of music, language, mind and body. Harvard University Press, Cambridge

Mithen SJ (2013) The cognition of *Homo neanderthalensis* and *H. sapiens*: does the use of pigment necessarily imply symbolic thought? In: Akazawa T, Ogihara N, Tanabe HC, Terashima H (eds) Dynamics of learning in Neanderthals and modern humans. Vol. 2 Cognitive and physical perspectives. Springer, New York

Nagoka L (2002) The effects of resource depression on foraging efficiency, diet breadth and patch use in southern New Zealand. J Anthrop Archaeol 21:419–442

Negash A, Shackley MS (2006) Geochemical provenance of artifacts from the MSA site of Porc Epic, Ethiopia. Archaeom 48(1):1–12

Peck JR, Barreau G, Heath SC (1997) Imperfect genes, fisherian mutation and the evolution of sex. Genetics 145:1171–1199

Powell A, Shennan S, Thomas M (2009) Late Pleistocene demography and the appearance of modern human behavior. Science 324: 1298–1301

Premo LS (2012) Local extinctions, connectedness, and cultural evolution in structured populations. Adv Complex Syst 15(1150002): 1–18

Premo L, Kuhn S (2010) Modeling effects of local extinctions on culture change and diversity in the Paleolithic. PLoS One 5(12):e15582

Richards M, Pettitt P, Trinkaus E, Smith F, Paunović M, Karavanić I (2000) Neanderthal diet at Vindija and Neanderthal predation: the evidence from stable isotopes. Proc Natl Acad Sci USA 97(13): 7663–7666

Richards M, Pettitt P, Stiner MC, Trinkaus E (2001) Stable isotope evidence for increasing dietary breadth in the European mid-Upper Paleolithic. Proc Natl Acad Sci USA 98(11):6528–6532

Richerson P, Boyd R, Bettinger R (2009) Cultural innovations and demographic change. Hum Biol 81:211–235

Riede F (2009) Climate and demography in early prehistory: using calibrated 14C dates as population proxies. Hum Biol 81:309–337

Schweizer T (1996) Reconsidering social networks: reciprocal gift exchange among the !Kung. J Quant Anthrop 6:147–170

Shea JJ (2006) The origins of lithic projectile point technology: evidence from Africa, the Levant, and Europe. J Archaeol Sci 33:823–846

Shea JJ (2011) *Homo sapiens* is as *Homo sapiens* was. Behavioral variability versus "behavioral modernity" in Paleolithic archaeology. Curr Anthrop 52(1):1–35

Shea JJ, Sisk M (2010) Complex projectile technology and *Homo sapiens* dispersal into western Eurasia. PaleoAnthropol 2010:100–122
Shennan S (2001) Demography and cultural innovation: a model and its implications for the emergence of modern human culture. Camb Archaeol J 11:5–16
Shennan S, Edinborough K (2007) Prehistoric population history: from the late glacial to the Late Neolithic in Central and Northern Europe. J Archaeol Sci 34:1339–1345
Slimak L, Giraud Y (2007) Circulations sur plusieurs centaines de kilomètres durant le Paléolithique moyen. Contribution à la connaissance des sociétés néandertaliennes. Comptes Rendus Palevol 6:359–368
Snodgrass JJ, Leonard WR (2009) Neandertal energetics revisited: insights into population dynamics and life history evolution. PaleoAnthrop 2009:220–223
Sorensen MV, Leonard WR (2001) Neandertal energetics and foraging efficiency. J Hum Evol 40:483–495
Steegman AT, Cerny FJ, Holliday TW (2002) Neandertal cold adaptation: physiological and energetic factors. Am J Hum Biol 14: 566–583
Stiner M (nd) An unshakeable Middle Paleolithic? Trends versus conservatism in predatory niche and their social ramifications. Curr Anthrop (in press)
Stiner MC, Kuhn SL (2008) Paleolithic diet and the division of labor in Mediterranean Eurasia. In: Hublin JJ, Richards M (eds) Evolution of human diets: integrating approaches to the study of Palaeolithic subsistence, Max Planck Institute for Evolutionary Anthropology. Vertebrate Paleobiolog and Paleoanthropology series, Germany subseries. Springer, Dordrecht, pp 155–167
Stiner MC, Munro ND (2002) Approaches to prehistoric diet breadth, demography, and prey ranking systems in time and space. J Archaeol Method Theory 9(2):181–214
Stiner MC, Munro ND, Surovell TA (2000) The tortoise and the hare: small game use, the Broad Spectrum Revolution and Broad Spectrum Revolution demography. Curr Anthrop 41(1):39–73
Stiner MC, Barkai R, Gopher A (2009) Cooperative hunting and meat sharing 400–200 kya at Qesem Cave, Israel. Proc Natl Acad Sci USA 32:13207–13212
Verpoorte A (2006) Neanderthal energetics and spatial behavior. Before Farm 2006(3):1–6, article 2
Wiessner P (1982) Risk, reciprocity and social influences on !kung San economics. In: Leacock E, Lee RB (eds) Politics and history in band societies. Cambridge University Press, Cambridge, pp 61–84
Wilkins J (2010) Style, symboling, and interaction in Middle Stone Age societies. Explor Anthrop 10(1):102–125
Wright KI (1994) Ground stone tools and hunter-gatherer subsistence in southwest Asia: implications for the transition to farming. Am Antiq 59(2):238–263
Wynn T, Coolidge FL (2011) How to think like a Neanderthal. Oxford University Press, New York
Yengoyan A (1979) Economy, society, and myth in aboriginal Australia. Ann Rev Anthrop 8:393–415

Cultural and Biological Transformations in the Middle Pleistocene Levant: A View from Qesem Cave, Israel

7

Ran Barkai and Avi Gopher

Abstract

In this paper we present our interpretation about the circumstances leading towards an evolutionary replacement of the earliest populations of the Levant, most probably *Homo erectus* (*senso lato*), by a new hominin lineage during the Middle Pleistocene, some 400,000 years ago. Our model suggests that dietary stress caused by the disappearance of elephants triggered the replacement of *Homo erectus*, a hominin highly dependent on consuming large animals, by a new hominin lineage that was better adapted to hunting larger numbers of smaller and faster animals in order to provide sufficient caloric intake to compensate for the loss of the elephants. The biological replacement took place in tandem with significant cultural changes embodied in a new, unique and innovative, local cultural complex in the Levant. It is our contention that the appearance of a new creative set of behaviors in the Levant some 400,000 years ago must have been accompanied by innovative cultural transmission mechanisms of a different nature than those practiced during earlier Lower Paleolithic times. These new learning behaviors must have played a significant role in the adoption and assimilation of new hunting methods, meat sharing, flint procurement and flint production strategies, as well as in the earliest habitual use of fire. The new cultural traits characterized humans in the Levant for a long period of over 200,000 years, to be replaced by the Middle Paleolithic Mousterian Cultural Complex created by both *Modern humans* and *Neanderthals*.

Keywords

Acheulo-Yabrudian • Cultural innovation • Learning abilities • Middle Pleistocene • Qesem cave

High dependence on the hunting and consumption of large mammals by some hominins may have limited their survival once their preferred quarry became scarce or disappeared. Adaptation to smaller residual prey would have been essential after the many large-bodied species decreased in numbers (Fa et al. 2013).

7.1 Introduction

The Lower Paleolithic period in the Levant lasted for over one million years (ca. 1.4–0.2 million years ago) and is most commonly characterized by the Acheulian Cultural Complex (Bar-Yosef 1994, 2006; Bar-Yosef and Belmaker 2011). It was most probably created by *Homo erectus* (*senso lato*) although human remains from this time period are scarce.

R. Barkai (✉) • A. Gopher
Department of Archaeology, Tel-Aviv University,
Tel-Aviv 69978, Israel
e-mail: barkaran@post.tau.ac.il; agopher@post.tau.ac.il

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_7, © Springer Japan 2013

While it is commonly stated that rather little behavioral and technological change is observed throughout the first million years of the Lower Paleolithic period in the Levant, the significant transformations that took place in this area toward the end of the Lower Paleolithic period, some 400,000 years ago, mark an undeniable departure from Acheulian lifeways. These local changes can be seen in the newly appearing, independent, local and innovative cultural complex in the Levant—the Acheulo-Yabrudian Cultural Complex (henceforth AYCC). This paper presents the major transformations that took shape in the Levant at the end of the Lower Paleolithic period, highlights the major differences between the Acheulian Cultural Complex and the AYCC and discusses the meaning and significance of this specific, local scenario of the human story in the Levant. We first review some of the relevant characteristics of the Acheulian Cultural Complex in the Levant (and beyond) and briefly describe the AYCC focusing our attention on evidence gathered during a decade of field work at the site of Qesem Cave. We then summarize differences between these two cultural complexes and finally, we discuss cultural and biological transformations in the Levant between 400,000 and 200,000 years ago.

7.2 The Acheulian Cultutral Complex: A Brief Overview

This overview is focused on the following subjects: lithic industries, faunal assemblages, the role of elephants in the diet and in culture, the debate regarding the use of fire, and finally, Acheulian hominins in the Levant.

7.2.1 Acheulian Lithic Industries

The Acheulian cultural complex in the Levant is generally characterized by the production of both small and large (over 10 cm) flakes and the manufacture of bifaces, known as handaxes or Large Cutting Tools (e.g. Barkai 2009; Machin 2009; Lycett and Gowlett 2008; Sharon 2009, 2010). While in Europe handaxe manufacture continued into the Middle Palaeolithic Mousterian, in the Levant, bifaces disappeared altogether from post-Acheulian Middle Paleolithic Mousterian industries (Goren-Inbar and Belfer-Cohen 1998, p. 206). Middle Paleolithic assemblages in the Levant are characterized by flake production and flake-tools, and a prominent use of the production strategy known as the Levallois technology. Common knowledge usually considers the Acheulian Cultural Complex as an epoch of technological stagnation, as clearly worded in a recent account on human brain evolution: "*Acheulian technology, mainly consisting of stone flakes and handaxes, made only limited progress for nearly 1.5 million years. This cultural and technological standstill contrasts with the rapid cultural explosion observed in the archaeological record that started approximately 250 kya, and is associated with the appearance of the first fossil remains of modern humans, Homo sapiens sapiens*."(Somel et al. 2013, p. 113). We consider such generalizations as judgmental and point out two significant aspects of Acheulian technological systems that such statements tend to ignore.

The first is the flexible application of flake and biface production technologies in Acheulian sites indicating significant behavioral, and most probably functional, variability (Goren-Inbar and Sharon 2006; Rabinovich et al. 2012).

The second is the recognition of a twofold technological change: (1) Handaxes showing an increase of refinement along time, as recently demonstrated in the early Acheulian from Konso, Africa: "*A clear increase of workmanship can be seen in edge modification and tip thinning. This sophistication resulted in larger flake scar counts, increase of plan form symmetry, and perhaps, some standardization of edge and tip shape/form. Handaxe functions were enhanced through time, and such tools might have emerged in association with advanced spatial and navigational cognition, perhaps related to an enhanced mode of hunting adaptation*" (Beyen et al. 2013); and (2) The emergence of prepared core technologies most probably took place during the late Acheulian, predating the classical Middle Paleolithic Levallois technology (e.g., Nowell and White 2010; Tyron 2006; Tryon et al. 2006; White et al. 2011; Wilkins et al. 2010). Notwithstanding these two significant technological developments, we agree that generally, viewing Acheulian technologies as demonstrating a relatively slow pace of change should not be ignored. However, in our view the long term technological continuity should not be accounted for as stagnation or lack of ability to innovate thereof, but rather be seen as part of the adaptability of Acheulian technologies. We see the long chronological span and the large geographical spread of Acheulian technologies as a testimony of their suitability for the survival of Acheulian hominins. The Lower Paleolithic archaeological record can thus indeed be accounted for as reflecting a most durable and successful phase in the history of the human race. The elaborate production of bifaces, the production of large and small flakes, and the significance of inter- and intra-site technological and typological variability as well as the application of predetermined flake production technologies are all indications of technological and behavioral capabilities of Acheulian hominins. It seems to us that the maintenance of specific technological systems for hundreds of thousands of years may be seen as evidence for stable and successful survival strategies practiced by well adapted and capable hominins. The interesting question *Vis á Vis* this issue is, in our opinion, not *why* has changes been so slow during the one million years of the Acheulian in the Levant, but *why* has this well-adapted system been changing and why have people taken the risk of adopting new technologies on account of the well tested and successful old ones. This is why the significant change in lithic production systems between the Acheulian and the AYCC is so interesting and asks for an explanation.

7.2.2 Acheulian Faunal Assemblages and the Role of Elephants

Acheulian sites in the Levant are mostly associated with large and medium sized mammals and the most common taxa represented are usually deer, bovids, equids, wild boar and more (see a recent summary and references in Bar-Yosef and Belmaker 2011), while the presence of megafauna, such as hippopotamus, rhinoceros and most significantly the elephants, deserve special attention (Ben-dor et al. 2011; Rabinovich et al. 2012). The significant role of elephants within Lower Paleolithic faunal assemblages is well attested in many sites in Europe (e.g., Anzidei et al. 2011; Aureli et al. 2012; Boschian and Saccà 2010; Mussi 2005; Saccà 2012a, b; Yravedra et al. 2010) and Africa (e.g., Echassoux 2012; Klein 1988 and references therein) however, the dietary significance of these huge food-package animals was not demonstrated or thoroughly discussed (but see Ben-Dor et al. 2011). It can be argued, that during Lower Paleolithic times in the Levant and during Lower *and* Middle Paleolithic times in Europe, elephants have been a constant source of calories for early hominins. By all means, this was only one source of calories amongst many other food resources, but in our opinion it was a significant one, a source of meat and fat to be depended on while present. While there are cases of associations of elephant remains and lithic artifacts, the human use of the elephants for dietary purposes is still debatable in some cases (e.g., Villa et al. 2005). Several Acheulian sites however, clearly demonstrate butchery and defleshing of elephants (Goren-Inbar et al. 1994; Rabinovich et al. 2012; Yravedra et al. 2010; Wenban-Smith et al. 2006). Post-Acheulian as well as Mousterian sites in Europe provide further evidence for the use of elephants both for clear dietary purposes, such as meat and marrow consumption (e.g., Blasco and Fernández Peris 2012; Yravedra et al. 2012), and for the use of elephant bones for other tasks (Anzidei 2001; Gaudzinski et al. 2005). We will elaborate on the non-dietary use of elephant bones in the Acheulian below.

The role of protein in human diet and subsistence in Lower Paleolithic times was demonstrated time and again in recent literature (e.g., Bunn 1981, 2006; Bunn and Ezzo 1993; Bunn and Kroll 1986; Milton 2003; Morin 2007; Pante 2012; Sahnouni et al. 2013; Shipman and Rose 1983; Shipman and Walker 1989) and it is commonly accepted that Acheulian and even pre-Acheulian hominins extracted a significant portion of the calories they consumed from animal meat and fat, and were actually dependent on animals for their survival (Ben-Dor et al. 2011; Domínguez-Rodrigo et al. 2012; Kaplan et al. 2000, 2007). Carnivory is thus a remarkable human trait accompanying humans since their earliest stages to this very day (Psouni et al. 2012). Notwithstanding the significant role we ascribe to meat and fat in the human diet, it goes without saying that a preservation bias is responsible for the absence of the vegetal component of early human diet and only extraordinarily preserved sites in special circumstances such as Geser Benot Ya'aqov (Goren-Inbar 2011 and references therein) reveal finds of this sort. It is most conceivable that Acheulian hominins consumed nuts, fruits, underground storage organs and other vegetal edible resources however, these were "side-dishes" so to speak to the main course served at Acheulian sites, which was composed of meat and fat. We argue that a significant aspect of meat and fat came from elephants, as long as elephants were available. It is true that Acheulian hominins consumed a large variety of other animals, but none of these resembles the "ideal" package of fat and meat offered by the elephant (see details in Ben-Dor et al. 2011). The archaeological evidence clearly demonstrates that Acheulian hominins were not indifferent to such ideal food-packages that roamed Africa, Europe, Asia and the Levant during the Pleistocene, and ate elephants continuously over hundreds of thousands of years. The hotly debated issue regarding hunting versus scavenging is beyond the scope of this paper and will be dealt with elsewhere. However, in our view, as recent hunter-gatherers demonstrate a large array of elephant hunting techniques, hunting elephants was within the capabilities of Acheulian hominins too (e.g., Janmart 1952; Marks 1976; Steinhart 2000). For us it seems unlikely to assume that the acquisition of such an important dietary source would be forsaken to be used only following elephants natural deaths or as part of a "food chain" of scavengers eating leftovers of other carnivores. We do not rule out the possibility of exploiting a dead or scavenged elephant, but most probably in addition to elephant hunting.

A short note regarding elephant representation in Acheulian sites in the Levant should be made. Albeit the extensive Lower Paleolithic research in this region, our data come from a limited number of excavated sites (Bar-Yosef and Belmaker 2011), of which a significant number reveal elephant remains in their faunal assemblages (Ubeidiya, Evron, Latamne, Gesher Benot Ya`aqov, Revadim and Holon, see Bar-Yosef and Belmaker 2011 for details and bibliography). All these sites are open-air sites as opposed to caves sites (Speth 2012). Acheulian presence in cave sites in the Levant is meager and the few cave sites showing Acheulian remains are either not rich in fauna or not thoroughly studied. Another point is that understanding the role of elephants within the faunal assemblages of Acheulian sites is dependent on the scale of the excavation and the size of the assemblages. At two Lower Paleolithic Acheulian sites that were systematically and rather extensively excavated and analyzed—Gesher Benot Ya`aqov and Revadim—the role of elephants as a constant and significant element of the diet cannot be ignored. At Gesher Benot Ya`aqov elephant remains are present in every archaeological level of the main excavation area in significant numbers (Rabinovich and Biton 2011) and in area B at the site of Revadim elephants are the dominant species with 155 identifiable bones (Rabinovich et al. 2012). Both sites show clear evidence for the use of elephants for dietary purposes, and even if our previous estimation regarding the caloric contribution of elephants to the human diet at the site of Gesher Benot Ya`aqov (Ben-Dor et al. 2011) can be discussed, the role of the elephant as a constant food source in this Acheulian site (as well as in other sites such as Revadim) is self evident from the archaeological record.

7.2.3 The Manipulation of Elephant Bones in the Acheulian

Acheulian hominins used the immense food-package of the elephant but they also made a remarkable use of elephant bones, mainly limb bones, in an extraordinary manner. While it is most probable that early hominins fractured elephant bones in order to extract marrow for dietary proposes, other endeavors were invested in using elephant bones beyond the nutritional or dietary realm.

The exploitation of elephant skull and limb bones to extract the brain and the marrow is clearly attested in several Pleistocene sites (e.g., Goren-Inbar et al. 1994; Saccà 2012a, b; Yravedra et al. 2010, 2011) and was studied both from the taphonomic and experimental perspectives (Haynes 1987; Haynes and Krasinski 2010; Holen 2006; Saccà 2012a, b). It is most probable that Acheulian hominins did not ignore the caloric potential of the marrow of elephant bones and extracted it, perhaps in simple ways used by recent hunter-gatherers (e.g., Fisher 1993, 2001; Haynes and Krasinski 2010; Holen and Holen 2007). Marrow extraction from elephant bones resulted in abundant broken bone fragments that resemble intentionally flaked bone flakes (Haynes and Krasinski 2010; Saccà 2012a, b). However, in many cases bone flakes removed from elephant bones, especially limb bones are different than the bone flakes and splinters resulting from bone fracturing for marrow extraction and it is rather clear that in many cases early hominins were intentionally flaking elephant bones producing bone flakes and shaping elephant bones (Haynes and Krasinski 2010; Saccà 2012a, b; Stanford et al. 1981).

While the most impressive and known Pleistocene archaeological sites with bone flakes and shaped bone tools made of elephant limb bones (Figs. 7.1, 7.2, and 7.3) are found in Europe (Anzidei 2001; Anzidei et al. 2011; Gaudzinski et al. 2005; Saccà 2012a, b; Segre and Ascenzi 1984), recent accounts reveal the presence of similar finds both in the Levant (Rabinovich et al. 2012) and in Africa (Beyen et al. 2013) and thus the manipulation of elephant bones should be considered as one of the Acheulian hallmarks. The purpose of flaking and shaping elephant bones still eludes us. Large and small bone flakes could be used in cutting, and the results of an experiment proposed the use of elephant bone flakes in cutting elephant meat, most effectively frozen meat (Stanford et al. 1981). Of course this could be practiced under specific climatic conditions, and thus accords well with the relative abundance of elephant bone flakes in Europe as opposed to their relative rarity in warmer areas such as Africa and the Levant. Shaped elephant bones, usually large items with a rather pointed edge, might be used in percussion activities, perhaps in breaking other elephant limb bones for marrow extraction (Saccà 2012b). The possibility of using tools made of elephant bones in order to further manipulate elephant meat and bone is significant. It involves not only reusing/recycling elephants' bones that originate from meat and marrow consumption, but closes a complete circle of human uses of elephants by using tools made of elephant bones. This striking behavior might be explained not only by practical reasoning, but also reflect a symbolic or cosmological scenario regarding the way Acheulian hominins perceived elephants. We may assume that when stone resources are readily available, they will be preferred for cutting and percussion activities. And so, if elephant bone flakes and tools took part in the exploitation of elephants and their processing where stone is abundant, a symbolic argument will not be too far fetched. The most striking phenomenon in using elephant bones is the shaping of elephant bone flakes to resemble Acheulian stone handaxe (Costa 2010; Saccà 2012a, b). In many cases the similarity to Acheulian stone bifaces is mind-blowing (Costa 2010; Mussi 2005), and one is left to wonder regarding the connection between stone bifaces, elephant exploitation and bifaces made of elephant bone in the Acheulian worldview (Figs. 7.1, 7.2, and 7.3). We might add to that two other striking phenomena that may assist understanding such a cultural perception; the first is the use of an "arrow-point" made of Mastodon bone for hunting a Mastodon found at the Manis site (USA, Waters et al. 2011), and the other is the presence of elephants engravings on of elephant bones in the European Upper Paleolithic (e.g., Braun and Palombo 2012). Albeit the different place, time, and context, these two cases evoke thoughts on possible ways of incorporating such man-animal interrelations into human culture.

Fig. 7.1 A biface made on an elephant bone from the Middle Pleistocene site of Fontana Ranuccio, Italy. Modified after Mussi 2005

Fig. 7.2 A biface on an elephant bone from the Middle Pleistocene site of Castel di Guido, Italy. Courtesy of G. Boschian

7.2.4 Fire and Raw Meat Eating in the Acheulian

> …bifaces that served…as multi-purpose tools, and were undoubtedly essential in chopping meat into small pieces that were consumed (and digested) raw. There is no need to view the knowledge of making fire as a universal practice; like other survival techniques, it could have been unique to certain social entities and not shared on a continent-wide basis (Bar-Yosef 2006, p. 490, our emphasis).

A major debate is taking place in recent years concerning the time and place of early human use of fire. Early fire occurrences, dating between 1.7 and 0.8 Ma (Lower and Middle Pleistocene) have been reported in sites such as Wonderwerk Cave and Gesher Benot Ya'aqov (Alperson-Afil and Goren-Inbar 2010; Beaumont 2011; Berna et al. 2012; Goren-Inbar et al. 2004). These indicate sporadic use of fire and were found at only a handful of Acheulian sites worldwide. Thus we concur with Bar-Yosef's statement presented above. Such "early fire" occurrences (Gowlett 2010) seem to have been on the scene until the late Middle Pleistocene and possibly as late as the Late Pleistocene in the Old World (Roebroeks and Villa 2011). The turning point from "early fire" to the habitual use of fire is a matter of dispute. Roebroeks and Villa (2011) relate to the habitual use of fire as a "systematically repeated use of fire in specific sites and/or regions." Based on an increased number of archaeological sites with evidence for fire, associated with evidence for fire being extensively used in domestic contexts, Roebroeks and Villa (2011) suggested that the earliest habitual use of fire occurs in Middle Pleistocene (ca. 400–300 ka) Europe and southwest Asia. On top of that, the purpose of the probable use of fire in the Acheulian was never demonstrated. It is clear that starting at ca. 400 ka, with the widespread appearance of the habitual use of fire, hearths were used in roasting meat and burned bones are found in abundance in post-Acheulian sites (e.g., Fernández Peris et al. 2010; Karkanas et al. 2007). This is clearly not the case in the Acheulian, and as far as we know, no Acheulian site in the Levant yielded burned animal bones. Thus in this case as well, we concur with Bar-Yosef's statement above that during the Acheulian, raw meat was consumed. The hypothetical model suggesting the role of cooking in human evolution even prior to the Acheulian must be

Fig. 7.3 Another biface on an elephant bone from the Middle Pleistocene site of Castel di Guido, Italy. Courtesy of G. Boschian

considered in this context (Carmody and Wrangham 2009; Wrangham and Carmody 2010; Wrangham et al. 1999), but at the moment we find this model to be ill supported by the archaeological evidence. To conclude this section we emphasize that as far as clear evidence goes, at the moment it seems that fire was not habitually used in the Acheulian and when present, was not involved in roasting meat.

7.2.5 Acheulian Hominins

> Throughout the Early Pleistocene, Homo erectus appears to have been the only type of hominin in Asia (Dennell 2009, p. 438).

As for the makers of the Acheulian in the Levant, the skeletal evidence is rarely found and not easily characterized (see a comprehensive summary of the evidence in Bar-Yosef and Belmaker 2011 and Dennell 2009). While some scholars refrain from classifying the probable hominin of the Acheulian in the Levant (Goren-Inbar 2011), most others strongly advocate a *Homo erectus* affiliation to the meager paleoanthropological evidence (Bar-Yosef and Belmaker 2011; Dennell 2009 and referenced therein).

7.3 The Acheulo-Yabrudian Cultural Complex with a Focus on Qesem Cave

7.3.1 The Acheulo-Yabrudian Cultural Complex

The Acheulo-Yabrudian Cultural Complex (AYCC) of the late Lower Paleolithic period in the Levant was defined by Rust (1950) following his 1930s excavation at Yabrud I in Syria. It comprises three major industries—Acheulo-Yabrudian, Yabrudian and Amudian (e.g., Garrod 1956, 1970; Jelinek 1990; Bar-Yosef 1994; Copeland 2000). The Acheulo-Yabrudian industry consists of a flake technology and is dominated by both handaxes (of Acheulian tradition) and scrapers. The Yabrudian is a flake industry with minor production of blades dominated by the conspicuous presence of Quina and demi Quina scrapers. And the Amudian is a blade-dominated flint industry.

Stratigraphically, the AYCC of the Levant repeatedly postdates the Lower Paleolithic Acheulian and predates the Middle Paleolithic Mousterian and is equivalent to Jelinek's (1990) "Mugharan Tradition." It is however important to note that the three industries intercalate within the AYCC stratigraphic columns. The absolute chronology of the AYCC was recently summarized and it covers a range of over 200 ka between 420 and ca. 200 ka (Gopehr et al. 2010 and references therein). New TL and ESR dates from Qesem Cave accord well with this range (Mercier et al. 2013).

AYCC sites are known from the central and southern Levant in both caves and open air settings; however most of the known sites are in caves or rock-shelters. The relatively small number of AYCC sites known at the moment does not allow, in our opinion, the establishment of a coherent settlement pattern of any kind. It might appear that caves were preferred, but this might well be biased by different factors (visibility; focus on cave research and more) or by the fact that AYCC open air sites might bear different characteristics than cave sites. At least in the case of Israel, we find it hard to believe that AYCC open air sites would not have been recognized in this extensively surveyed piece of land. Having said that, the study of AYCC settlement patterns will have to wait for further discoveries and new research designs. AYCC sites stretch from a line between the Syrian coast to the El Kowm basin in the north, through the Galilee (including the Mt. Carmel and the Jordan rift valley) in northern Israel and southwards to Tel Aviv, with Qesem Cave being the southernmost site known to date. This is a well defined and local entity with no sites known yet in the more southern arid parts of the Levant. It is interesting whether southern arid areas were not occupied during that time, or maybe, again we are facing some sort of a bias. The hypothetical possibility of Acheulian persistence in desert areas while it was replaced by the AYCC in Mediterranean zones cannot be ruled out, but needs more work and as far as the available data goes this is rather unlikely. We do not rule out the possibility that the replacement of the Acheulian by the AYCC was a prolonged process, and during that time a mosaic of archaeological phenomena could be seen on the landscape. However, in our opinion, the AYCC shows major differences in almost every realm compared to the Acheulian and thus the chances of Acheulian persistence are unlikely to be very high. In any case, the lack of good chronological control over the late Acheulian (e.g. Gopehr et al. 2010) hampers clear statements on the issue and the resolution is far from being sufficient for such studies at the moment. It is of note that recently an Acheulo-Yabrudian occupation was reported from Dederiyeh Cave in Syria that adds another important site to the list of the AYCC (Nishiaki et al. 2011).

Blade production in the Amudian industry is of special interest and is one of the major innovations of the AYCC (e.g. Bar-Yosef and Kuhn 1999). In the sites of Zuttiyeh, Yabrud I and Tabun Layer E blade industries were a minor component first referred to by Rust (1950) as “Pre-Aurignacian” and later termed Amudian (Garrod 1956, 1970; Garrod and Kirkbride 1961). This blade industry was found in relatively thin stratigraphic units at Tabun Cave and Yabrud I representing what was considered a minor or episodic component of the AYCC.

Middle Pleistocene blade production is and was always considered a major technological innovation sufficiently unique to be described as “ahead of its time.” Both Rust and Garrod suggested that they were made by distinct immigrating population interacting with the local flake-producing groups (Garrod 1970; Rust 1950, pp. 129–130). Jelinek (1990), on the other hand, suggested that this industry evolved within the local Mugharan (our AYCC) Tradition.

Amudian assemblages have been recovered in a small number of sites in the Levant such as Zuttiyeh, Yabrud I, Tabun layer E, Abri Zumoffen/Adlun, and Masloukh (Garrod and Bate 1937; Garrod and Kirkbride 1961; Gissis and Bar-Yosef 1974; Rust 1950; Skinner 1970; Turville-Petre 1927). Studies of the Amudian industry were however sparse due to the relatively small samples obtained from complex stratigraphic sequences, usually occurring within alternating lithic industries. Thorough studies of Amudian lithics have been undertaken for Tabun (Jelinek 1990; Monigal 2001, 2002; Wiseman 1993), Yabrud (Vishnyatsky 2000), Abri Zumoffen (Copeland 1983), and Masloukh (Shmookler 1983). The Amudian industry is characterized by systematic blade production and a major component of tools made on blades. Alongside blade production, a significant component of flakes also appears in the Amudian, and side scrapers appear in various frequencies (Copeland 2000; Jelinek 1982, 1990; Monigal 2001, 2002, pp. 270–271).

Qesem Cave is a significant addition to the above list firstly because it has shown that the Amudian represents a major industry of the AYCC, equivalent in time and scale to the other known industries, and secondly, because it provided large, well preserved, none disturbed, thoroughly recovered and well dated Amudian assemblages enabling a systematic study of the Amudian blade industry (e.g. Gopher et al. 2005; Barkai et al. 2005, 2009; Shimelmitz et al. 2011).

A short note on the Yabrudian industry is in order here; the important aspect of this industry is the innovative appearance of the Quina *Chaîne Opératoire* for the shaping of Quina scrapers (see Bourguignon 2001). These scrapers are quite distinctive and well known from Middle Paleolithic Mousterian of Europe, however the Yabrudian is much older than the European manifestations and shows the Quina phenomenon and scrapers as early as 420–200 ka ago in the Levant. It is thus quite untenable to suggest any kind of connection between the two very similar or almost identical, Quina phenomena. Moreover, even in the Levant, where Quina scrapers appear so clearly in the Yabrudian industry of the AYCC and in very large numbers (many hundreds at Qesem Cave and thousands at Tabun Cave), the technology and the tools cease to appear in post-AYCC Middle Paleolithic Mousterian sites in the region and are unknown from earlier Acheulian contexts. This makes their presence in the Yabrudian quite intriguing and this issue will have to be tackled in the future. It is important to note the fact that Quina scrapers of Yabrudian technology and workmanship appear in the Amudian industry too, at least in the case of Qesem Cave, however in low frequencies. Combined with the fact that the Yabrudian at this site produces low percentages of blades made by the same technology and on similar raw material as the Amudian blades, this promotes the idea that the two industries are parts of a single industrial complex made by the same people and the differences between them reflect variation in toolkits and/or activities, and this issue is to be tackled in future research as well.

7.3.2 Qesem Cave

Qesem Cave discovered in the year 2000 is a Middle Pleistocene site in Israel dated by various methods to 420–200 kyr—a crucial period in human biological and cultural evolution. The whole stratigraphic column of Qesem Cave is securely assigned to the AYCC (Barkai et al. 2003; Gopher et al. 2005; Barkai and Gopher 2011) and thus postdates the Acheulian and predates the Middle Paleolithic Mousterian. Ongoing research at the site provides ample evidence of many innovative behaviors some of which have been referred to in recent years, as “modern human behavior” (e.g. Nowell 2010 and references therein). This pertains for example to serial blade production (Barkai et al. 2009; Gopher et al. 2005; Shimelmitz et al. 2011) and for Qesem Cave we may add the acquisition of raw material for selected tool types from deep underground sources (Verri et al. 2004, 2005; Barkai et al. 2009; Boaretto et al. 2009) as well as the production of Quina scrapers using classical Quina technology; group hunting of prime age animals (mainly fallow deer), specialized butchering techniques and unique meat sharing habits (Stiner et al. 2009, 2011); the habitual use of fire (Karkanas et al. 2007); hearth centered spatially patterned activities (Barkai et al. 2009; Stiner et al. 2009, 2011); and more, all well established at Qesem Cave.

Qesem Cave is a sediment filled karstic chamber (some 300 m^2 in size and ca. 10 m high) located 12 km east of Tel Aviv at elevation 90 m.a.s.l. in a Mediterranean landscape (Fig. 7.4). Qesem Cave is part of larger karstic systems within the limestone of the B'ina Formation of the Turonian era. The cave seems to have developed as an isolated phreatic cave and became available to humans in the Middle Pleistocene following slope erosion (Frumkin et al. 2009).

The 9.5 m stratigraphic sequence was divided into two parts—the lower (ca. 5 m thick), consists of sediments with clastic content and gravel, and the upper (ca. 4.5 m thick) of cemented sediment with a large ash component (Figs. 7.5 and 7.6). The lower part was deposited in a closed karstic chamber cave, while the upper part was deposited when the cave was more open as indicated by the presence of calcified rootlets (Karkanas et al. 2007). The use of fire at the site is

Fig. 7.4 Location of Qesem Cave

Fig. 7.5 Qesem Cave: a view from East to West. An overview of the lower part of the sequence

Fig. 7.6 Qesem Cave: a view from West to East. An overview of the upper part of the sequence

Fig. 7.7 A central hearth from Qesem Cave (at the back of the picture). Notice ash layers inclined from East to West (right to left in the picture)

apparent throughout the sequence not only by abundant burnt bones and burnt flint items (Lemorini et al. 2006; Stiner et al. 2009, 2011; Mercier et al. 2013) but also by the presence of ash in the sediments (Karkanas et al. 2007, and Fig. 7.7).

Intensive $^{230}Th/^{234}U$ dating on speleothems suggests human occupation starting ca. 400 kyr and ending prior to 200 kyr (Barkai et al. 2003; Gopehr et al. 2010). This is supported by a series of TL and ESR dates (Mercier et al.

Fig. 7.8 Examples of anthropogenic damageon bones from Qesem Cave: (**a**) cut marks on several limb bone fragments of *Dama cf. mesopotamica* and details of incisions; (**b**) burning damage (double colouration) on long bone fragments of small and large-sized animals; (**c**) impact notches on limb bone fragment of a medium-sized ungulate. Courtesy Ruth Blasco

2013). The two major assemblages found at the cave are faunal remains and lithic artifacts—both counting hundreds of thousands of items by now.

The rich faunal assemblages of Qesem cave are dominated by prime-age fallow deer (*Dama cf. mesopotamica*) (74–80 % of the identified specimens in all strata) most probably indicating systematic hunting carried out cooperatively. The fauna also includes small numbers of wild ass, horse, wild boar, red deer, roe deer, aurochs, rhinoceros, wild goat and tortoise. Selected body parts were brought to the cave and the abundant cut marks show a specialized butchering pattern and a possible unique meat sharing behavior (Stiner et al. 2009, 2011). Many of the bones are burned, broken and demonstrate intensive human manipulation (Fig. 7.8). No elephant remains were found.

A rich assemblage of micromammals and reptiles was collected in two areas within the cave dated to >300 kyr

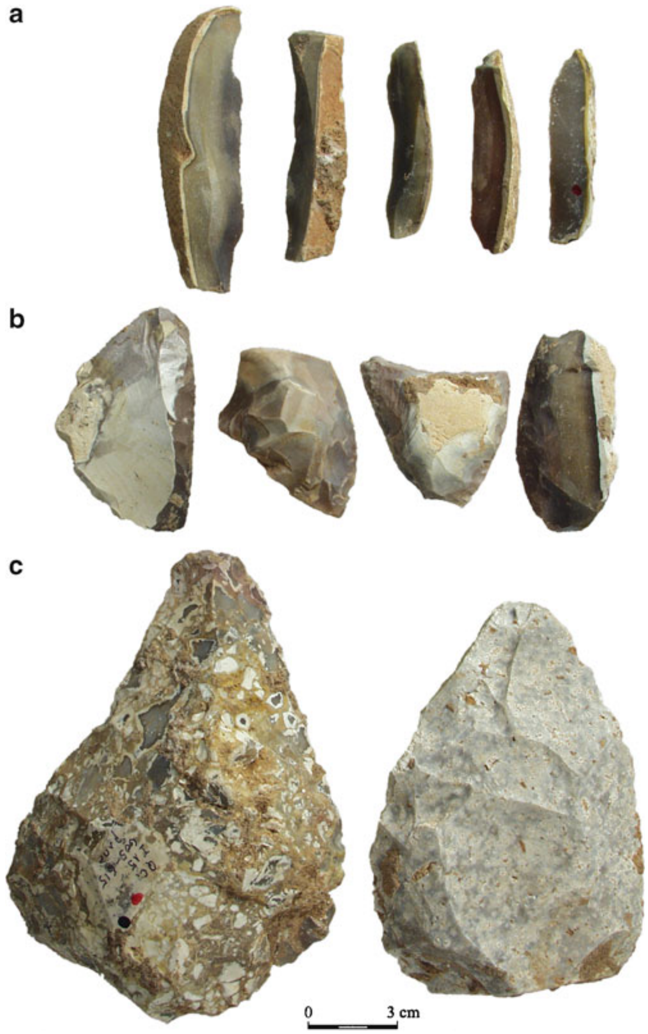


Fig. 7.9 Blades from Qesem Cave

(Maul et al. 2011). The identified taxa mostly appear in Israel up to the present day and they enable to infer a paleoenvironment with a mosaic of open and woodland habitats (Maul et al. 2011). An unusual aspect in the assemblage is the superabundance in the reptilian component of a single species of *Chamaeleo* (Smith et al. 2013).

Two of the three AYCC industries are present at Qesem Cave and while the Amudian is dominant throughout the cave's stratigraphic sequence, the Yabrudian is less conspicuous and appears in restricted, well defined parts of the sequence.

The Amudian blade industry is dominant throughout the stratigraphic sequence characterized by systematic blade production and a major component of shaped blades and Naturally Backed Knives (Fig. 7.9). Alongside blade production, flakes also appear in the Amudian as well as some scrapers and single handaxes (Barkai et al. 2005, 2009; Gopher et al. 2005; Shimelmitz et al. 2011). Blade production reflects thorough raw material selection and a full *Chaîne Opératoire* of blade production, shaping, use and discard. Amudian blades were mostly used in cutting, butchering and defleshing activities on soft tissues and were practically conceived as disposable, shortly used tools (Lemorini et al. 2006).

The Yabrudian (Barkai et al. 2009) shows a conspicuous dominance of Quina scrapers in the shaped items (almost 50 %) while blades are scarce. As opposed to the case of blade production, the *Chaîne Opératoire* for Quina scrapers is missing from the cave and only some debitage items of shaping, resharpening and retooling these scrapers are found. We thus assume that selected flakes or finished scrapers were imported into the cave. Yabrudian assemblages do include small numbers of blades produced in Amudian standards. Our working hypothesis is thus that the Amudian and Yabrudian lithic industries at Qesem Cave were indeed produced by a single group of hominins that occupied the cave time and again throughout the AYCC. Although bifaces are indeed marginal at Qesem Cave, and appear as single items in both Amudian and Yabrudian assemblages (Barkai et al. 2013), we may say that the three lithic hallmarks of the AYCC: blades, Quina scrapers and handaxes are represented at the cave in various frequencies in different contexts. While this general statement is not so relevant for bifaces at Qesem Cave, it is very significant for blades and Quina scrapers. A detailed technological analyses of blades and scrapers shows that they were produced by the same technology and standards (as well as respective raw materials) in both the Amudian and the Yabrudian industries supporting our claim for a single group using the same technologies. The various frequencies of the different components of the assemblage reflect a space division into activity areas, each characterized by the dominance of one of the components, blades or Quina scrapers, over the other. Field relations and radiometric dates recently obtained (Mercier et al. 2013) strongly suggest that blade-dominated and scraper-dominated assemblages are contemporaneous, reinforcing our view that AYCC lithic variability reflects activity areas rather than distinct human groups.

In a recent study minuscule flakes made from recycled flint and used to cut meat were identified (Barkai et al. 2010). The tiny flakes were removed from the ventral face of the parent-flake ("core-on-flake") with little or no preparation. These minuscule flakes are not longer than 1–3 cm and by convention, not thoroughly studied. Experiments with replicas verified that the flakes were razor-like implements, sharp enough for users to easily cut muscles, tendons, or skin, while their size restricted their efficiency in cutting deep muscles. Absence of hafting traces on the minuscule flakes indicates that they were probably hand-held. Our experiments suggested that these sharp flakes might facilitate butchering of small animals or tasks such as cutting of skin or sinew strips in larger animals. Many of these minuscule implements had two lateral sharp edges and a typically dull (hinged) distal end, making them "safe" for use near the mouth. Thus, they might have also been used as hand-held knives while eating. Moreover, for instant and rapid actions requiring sharp implements, they would have presented an excellent solution, easily achieved via a simple knapping technique based on recycling of old discarded flakes.

One of the most innovative aspects of the Qesem Cave lithic finds is the very early (global) presence of well established serial production of flint blade-knives. Additional innovative aspects are the intense re-use and recycling of flint items (e.g. Barkai et al. 2010); the almost total absence of handaxes characteristic of the preceding Acheulian; and the early appearance of Quina and demi-Quina scrapers. The *Levallois technique*, characteristic of succeeding Mousterian industries, is absent at Qesem Cave. Our reconstruction of Amudian technology and tool typology thus highlights innovative human behavior concerning production, use and discard of flint blades while the study or the world's earliest Quina scrapers is currently underway. It should be mentioned that other early blade industries were recently reported from Africa (Johnson and McBrearty 2010; Wilkins and Chazan 2012) and the interrelations between these industries and the Amudian is intriguing. However, the African early blade industries appear to be different than the Amudian in scale and technology, and their temporal and contextual resolution as far as the currently published data go are rather low. For example, it would be interesting to know what fauna accompanies these industries; what were the blades used for; what types of tools were shaped on these blades; what other tool-types appear in these assemblages and how long did these early African blade industries persist. Until such studies are available, it is still premature to compare the Amudian to the African industries although the suggestion of a multiple origins hypothesis for early Middle Pleistocene blade technology (Wilkins and Chazan 2012) should not be ruled out. It is our contention that the Amudian blade technology emerged in the Levant as an original innovative behavior of the AYCC. The absence of any African elements in the lithic and faunal assemblages at Qesem Cave supports such view, as well as the fact that the Yabrudian industry has no counterparts in Africa.

We claim that the two technological innovations, i.e. systematic blade production and Quina scraper production are part of a local wave of innovation that took place in the Levant and was aimed at the manipulation of medium-sized game. A recent study of Mousterian Quina scrapers from France (Claud et al. 2012) shows their use as butchering tools, and preliminary functional observations on the Qesem scarpers supports such a view (although hide working was observed too, Lemorini Per. Comm.). We thus suggest that the Amudian blades and the Yabrudian scrapers were two components of a new butchering and meat-cutting set that was developed in the Levant around 400 ka for the first time after hundreds of thousands of Acheulian years in order to support new hunting and meat sharing practices following the loss of calories previously obtained from elephants. This particular combination of blades and Quina scrapers is not known elsewhere and reflects specific conditions and a specific adaptation that has, as far as we know, no counterparts in Africa or Europe. The specific circumstances that led to the appearance of early blade industries in Africa and the Mousterian Quina industries of Europe are yet unexplained, but this is beyond the scope of this paper. We would like to say that in our view, the specific AYCC adaptations and innovative new technologies and shaped tools are not necessarily the only way to survive, and it might well be that continued hunting, butchering and cutting medium-sized mammals could go on using the Acheulian tool kit, or, for that matter, any other tool kit (a Levallois tool-kit, for example). We suggest, however, that within the framework of the major transformations that took place around 400 ka in the Levant, mostly the disappearance of the elephant from the human diet and the biological selection in favor of hominins better adapted to hunting larger numbers of medium-sized mammals, the innovation, assimilation and adoption of new lithic technologies were made possible as new components of a new economic and most probably social order.

Another most important find of Qesem Cave is the few human dental remains. These were studied recently (Hershkovitz et al. 2011) and considering the evidence in its entirety, it appears that the Qesem teeth are clearly not of *Homo erectus* (senso lato) and seem to be more Skhul/Qafzeh like although Neanderthal traits are present too. In a recent paper we suggested that these teeth represent a new, locally developed, post *Homo erectus* hominin lineage in the region (Ben-Dor et al. 2011). These results are consistent with the recently published innovative model for the evolution of the human Pleistocene populations of Europe (Bermúdes de Castro and Martinón-Torres 2012), suggesting the Levant as the Central Area of Dispersals of Eurasia (CADE), an "origin region" for human species biodiversity (and see below section on hominin lineages).

7.4 Major Transformations Between the Acheulian and the Acheulo-Yabrudian Cultural Complexes in the Levant

Here we summarize and highlight the cultural and biological transformations that took place during Middle Pleistocene times in the Levant, around 400 ka, and point out the major differences between the Acheulian and Acheulo-Yabrudian cultural complexes in the Levant.

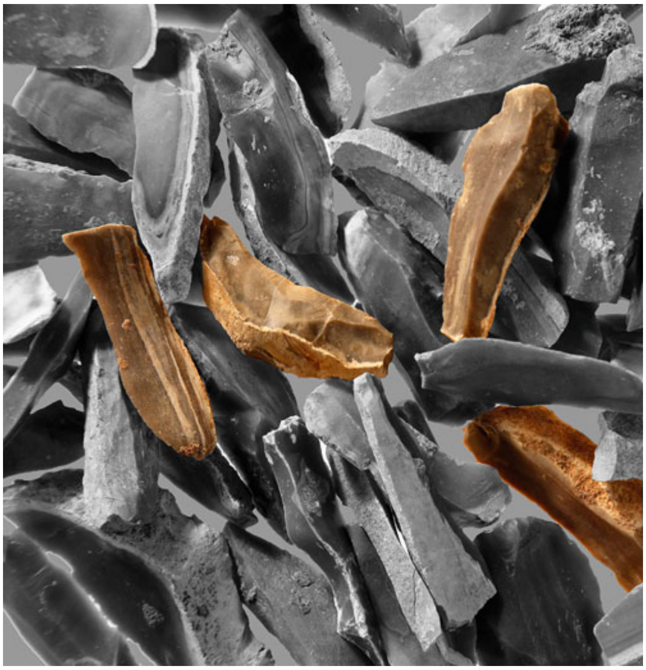


Fig. 7.10 Blades, Quina scrapers and bifaces from Qesem Cave

7.4.1 Fire and Cooking

The use of fire in the Acheulian seems to be sporadic and was not shared by all Acheulian groups, at least as far as the current evidence goes. In the cases where the use of fire was suggested, no evidence (burned bones) for its use for meat roasting was presented and it appears that meat and fat were consumed raw during Acheulian times.

In the AYCC starting ca. 400 ka ago, the use of fire became habitual. Evidence of fire is found at Qesem Cave throughout the 200 ka years of human occupation and the abundance of burnt bones (Fig. 7.10) indicates the use of fire for cooking (see Speth 2012 for a suggestion regarding cooking) and meat roasting. Both the habitual use of fire and meat roasting (and cooking?) continued in the Levant after the AYCC and characterized humans of Middle Paleolithic times as well as later periods.

7.4.2 Diet

7.4.2.1 The Role of Elephants

> Elephants had already vanished from most if not all of the region before the onset of the MP, almost certainly prior to 300 ka, and perhaps already by 400 ka or more (Speth 2012, p. 10).

Elephants were part of the diet of Acheulian hominins and elephant bones were found in Acheulian sites in the Levant throughout the one million years span of the Acheulian Cultural Complex. Although the chronological resolution of the Acheulian if far from being sufficient, it is argued here that elephant bones are present in early, middle and late Acheulian sites (Ubeidya, Evron; Gesher Benot Ya'aqov; Revadim, Holon respectively), and thus we may say that whenever people were present they made use of elephants, mostly for dietary purposes. We cannot argue here that elephants were present in the Levant throughout the entire one million years represented by the Acheulian Cultural Complex. All we say is that humans in the Levant during the Acheulian are constantly associated with elephants and use them as a source of food. In our view, elephants constituted a significant part of the human diet in Acheulian times. It should be noted, however, that although elephant bones are not present in every Acheulian site in the Levant, their presence at sites excavated to a relatively large extent might hint that limited field exposures hampers our understanding of the role of elephants in some Acheulian sites. It is of course possible that elephants were not consumed at every Acheulian site and that in certain times and certain places Acheulian hominins in the Levant survived with no elephant meat and fat on the menu. However, in our opinion, this was the exception rather than the norm.

Sites of the AYCC as well as later sites in the Levant, lack elephant remains. No elephant bones were found at any post-Acheulian site in the Levant, open-air and cave sites included (notwithstanding stray, random, single specimens that might occur). Elephants were not part of post-Acheulian human diet, which was based on medium-size prime-age animals both in the late Lower Paleolithic AYCC and the later Middle Paleolithic Mousterian (e.g. Speth 2012).

7.4.2.2 Hunting

Clear evidence for hunting in the Acheulian is a complex matter and may be in many cases beyond the available archaeological data. The subject is thus under continuous debate. For this matter, we adopt the well-known saying that "The absence of evidence in not evidence of absence" and we strongly believe that hunting, including elephant hunting was within the reach and was practiced by Acheulian hominins. We believe, so but have no "killing arguments" and so other people might believe otherwise and it remains an open question.

In the case of the AYCC and Qesem Cave, an argument towards animal acquisition by hunting was convincingly presented based on targeting prime-aged individuals and body part selection and transportation (Stiner et al. 2009, 2011). It is commonly accepted that during Middle Paleolithic times, Mousterian hominins were obtaining calories from meat by hunting (e.g. Speth 2012), so there should be no major debate on a statement that people clearly hunted in the AYCC and continued to do so afterwards.

7.4.2.3 Meat Cutting and Sharing

As people were eating meat starting in the early Pleistocene, it goes without saying that they were engaged in cutting meat. The study of cut-marks has developed significantly in recent years, and more evidence has accumulated. The best evidence for fallow deer (*Dama mesopotamica*) cutting in the Lower Paleolithic Levant comes from the site of Gesher Benot Ya'aqov (Rabinovich et al. 2008) indicating a clear understanding of prey anatomy and surgical cutting, very similar to the way it is being done by recent hunter-gatherers. Similar butchery and cutting patterns were identified in Middle and Late Paleolithic contexts (e.g. Speth 2012) and it seems that in this respect Acheulian hominins were cutting meat in a way similar to later hominins. Dismembering, defleshing and butchering activities were conducted by experienced butchers and it is most reasonable to assume that meat parts were split into manageable pieces to be distributed between group members present at the scene. Meat sharing is one of the most significant social mechanisms in recent hunter-gatherers groups (see Stiner et al. 2009) and cut marks evidence may suggest a similar behavior in Lower and Middle/Upper Paleolithic times.

At Qesem Cave however, it seems that meat cutting was performed differently (Stiner et al. 2009, 2011). Lacking cut mark evidence from other AYCC sites we are left to wonder if this extraordinary cutting pattern is specific to Qesem only or is characteristic of AYCC (see Speth 2012 for a discussion on the subject). We would raise our fingers in favor of the second option, but would wait for more evidence to come. In any case, at Qesem Cave meat was cut in a way which is not surgical and is not known from other sites and periods. Cut marks are relatively abundant, but their orientation and distribution as well as the relation between the different cut marks are different than in other time periods (Fig. 7.10). The meaning of this pattern is still not clear, but we have suggested that the general pattern presented previously, based on the ethnographic record in which one skilled individual cuts the meat for the rest of the group, is not the case at Qesem Cave. The unique pattern of cut marks at Qesem Cave is found throughout the sequence of the cave indicating a continuous use of this butchery pattern throughout the human use of the cave. So, people during the AYCC at Qesem Cave were cutting meat in a specific way, different than the earlier Acheulian or the later Mousterian and different than recent hunter-gatherers. We could speculate that different meat sharing patterns were practiced as well, and therefore one of the major socio-economic mechanisms in hunter-gatherer societies took a different shape during AYCC times. In Middle Paleolithic Mousterian times, postdating the AYCC, meat cutting patterns and most probably sharing practices came back to "normal."

7.4.3 Lithic Industries

7.4.3.1 Lithic Technology

Acheulian lithic technological systems were based on flake and biface production. Acheulian flake production was far from being simple and homogeneous. Acheulian hominins practiced varied flake production methods (e.g. Sharon 2009), produced flakes in different dimensions (very large, very small, and in all sizes between these extremities) and have shown high dexterity and technological abilities. The same goes for biface production. Acheulian hominis perfectly controlled bifacial flaking and produced a large variety of bifacial tools in different sizes, shapes and refinement levels. Moreover, it is well accepted that prepared core technology aimed at the production of predetermined blanks appeared within Acheulian lithic industries (e.g. Nowell and white 2010).

Biface and flake production continued in the AYCC, and this is the major reason why early excavators related this cultural phase to the Acheulian. However, two new lithic production technologies appeared for the first time in the AYCC of the Levant, after 400 ka: Systematic blade production and Quina scraper production. Each of these new technologies represents newly developed *Chaîne Opératoires*, meaning clear and repetitive patterns of raw material procurement strategies and selection; blank production technologies; tool shaping and function as well as resharpening and recycling (or the lack of). Both the blade and the Quina scraper concepts in the AYCC appear well ahead of their time, meaning much earlier than commonly expected and both reflect Levantine post-Acheulian technological innovations. It should be noted that these two lithic aspects characterize the AYCC of the Levant only and seize to appear as soon as it was replaced by the Middle Paleolithic Mousterian Cultural Complex.

7.4.3.2 Lithic Creativity

Acheulian lithic technologies can indeed be seen as conservative in terms of creativity and innovativeness, however the invention and assimilation of prepared core technologies should not be overlooked (Nowell and White 2010).

The AYCC, on the other hand, demonstrates a "creativity revolution" so to speak. New lithic technologies were invented, assimilated and adopted. Innovative blade and scraper production appeared and were maintained for a period of 200,000 years reflecting a society that is open to innovative elements and is willing to adopt new production technologies.

7.4.3.3 Lithic Recycling

Relatively little is known about lithic recycling in the Acheulian, however resharpening and extending the use-life of handaxes is rather well studied. Evidence for systematic lithic recycling has been documented at the late Acheulian site of Revadim, however detailed accounts have not yet been published so a discussion on the possible role of recycling in the Acheulian is still premature.

At Qesem Cave, abundant evidence for lithic recycling, namely the systematic use of "old" flakes and tools for the manufacture of small cutting tools (produced mostly from the ventral face of the "parent" flake) were noticed and are currently under study. We have identified similar phenomenon in other AYCC sites and thus propose that lithic recycling might be regarded as one of the hallmarks of the AYCC and should be taken into account in reconstructing flint economy of post-Acheulian times in the Levant.

7.4.3.4 Stone Quarrying

We are still far from being familiar with Acheulian lithic procurement strategies in the Levant. In most cases we have no information regarding the sources and techniques used for providing flint during Acheulian times. In the last decade large flake production and biface production were found within extensive flint extraction and reduction complexes in northern Israel, however these complexes were exploited mostly during Middle Paleolithic times and their role in the Acheulian still needs to be evaluated (e.g. Barkai and Gopher 2009; Gopher and Barkai 2011).

In the AYCC, concrete evidence for flint procurement by both surface collection and quarrying were presented and it is clear that post-Acheulian hominins were engaged in flint quarrying from specific, designated sources. It was suggested that the investment in raw material procurement was directed towards the production of specific tool types (Boaretto et al. 2009) and thus reflects a new lithic economy that was developed in the post-Acheulian Levant.

7.4.4 Hominin Lineages

As argued earlier, it is most conceivable that the Acheulian Cultural Complex in the Levant was created by *Homo erectus* (*senso lato*).

The dental evidence from Qesem Cave supported by the Galillee-Man skull from Zuttiyeh Cave (Freidline et al. 2012; Keith 1927; Zeitoun 2001) hint towards a new, post-Acheulian, post-*erectus* hominin lineage in the Levant at ca. 400,000 years ago. This statement is supported by new studies of Middle Plesitocene skeletal remains, mainly dental remains from the Levant and beyond (Le Cabec et al. 2012; Liu et al. 2013; Rink et al. 2013) as well as genetic evidence recently published suggesting a Middle Pleistocene (pre 300 ka) date for the ancestors of Modern humans and/or Neanderthals (e.g. Endicott et al. 2010; Mendez et al. 2013).

7.5 Creativity and Innovative Behavior in the AYCC: The Role of Learning and the Transmission of Knowledge

It has been argued recently that the unique prolonged period of childhood in humans might have developed as an evolutionary mechanism allowing the long acquisition of survival skills. This specific human trait might have emerged with the appearance of *Homo erectus*, almost two million years ago (e.g. Nowell and White 2010 and references therein). It was also suggested that the complex skills needed in order to survive in Early and Middle Pleistocene environments of the Old World were transmitted in *Homo erectus* groups by teaching and learning, although the archaeological evidence for such behaviors is mostly translucent and difficult to attain; other scholars argue in favor of imitation over learning (e.g. Bar-Yosef 2006; Nowell and White 2010; Shipton 2010; Winton 2005). Studies of recent hunter-gatherer societies strongly support the notion of knowledge transmission mechanisms starting in a very early age and aimed at providing the young individuals in the group, either by direct teaching or by providing the opportunities to learn, with the necessary skills in order to be able to support themselves and act as expected from a group member (e.g. Hewlett et al. 2011; Keith 2006). Most ethnographic studies focused on two of the most significant tasks in hunter-gatherers life-ways: hunting and tool making (e.g. Blutron Jones and Konner 1998; Blutron Jones and Marlowe 2002; MacDonald 2007; Stout 2005), but it can be assumed that knowledge regarding other tasks, such as gathering, food preparation, butchering etc., was also transmitted by similar teaching and learning mechanisms (e.g. Blasco et al. 2013). Archaeologists have been trying to study the transmission of knowledge mainly in the realm of stone tool production and have produced very interesting results regarding the probable existence of apprentice procedures and teaching and learning mechanisms in many prehistoric cultures and periods, the Lower Paleolithic included (e.g., Eren et al. 2011; Ferguson 2008; Finaly 1997; Geribas et al. 2010; Grimm 2000; Hallos 2005; Hogberg 2008; Horsholm 1990; Hovers 2009; Loshe 2011; Nonaka et al. 2010; Pigeot 1990; Shipton 2010; Sorensen 2009; Stout et al. 2011; Winton 2005). Other studies have focused on other aspects than stone tool production and have emphasized knowledge transmission mechanisms that allow children to acquire skills and capabilities in ancient and contemporary hunter-gatherer societies (e.g. Arnold 2012; Hewlett and Lamb 2003; Kamp 2001a, b; Lillehammer 1989).

The plethora of literature presented above supports, in our opinion, the suggestions regarding the significant role of knowledge transmission mechanisms in Lower Paleolithic societies in particular and in human prehistory in general. We strongly believe that daily activities preformed by Acheulian hominins, as well as social norms and behavioral practices, had to be taught and learned. *Homo erectus* offsprings had to acquire knowledge regarding stone tool manufacture, and in particular the principles of biface reduction, meat and fat procurement strategies, butchering, vegetal material gathering and many more skills needed in order to survive, not to mention the social skills needed in order to live in a socially dynamic community. Notwithstanding the significant role of these transmission mechanisms during Acheulian times, one should not ignore the relatively slow pace of change described above and the fact that these skills were transmitted over and over again throughout a period of over one million years in the Levant.

Starting 400,000 years ago, in the course of the AYCC in the Levant, different knowledge transmission mechanisms must have been developed in order to support the success of newly adopted survival strategies. In addition to the production of flakes and bifaces, AYCC hominins had to learn how to produce blades and Quina scrapers following strict standards. Moreover, knowledge and skills regarding the identification of flint sources and quarrying techniques and procedures had to be transmitted, as well as the concept and practice of flint recycling. The focus on hunting prime-aged fallow-deer, those with the highest fat content in the herd, necessitated very precise identification of specific deer to be targeted according to the color of the fur and the brightness of the skin. It is not without a reason that the Saami of northern Norway, for example, use more than 600 words for reindeer according to their age, sex, color, coat, antler etc. (Clottes 2013). So tracking game and hunting must have been a practice based on specific knowledge and experience. Since we strongly believe that Acheulian hominins hunted game, elephants included, it comes without saying that parts of the tracking and hunting procedures of the AYCC were already practiced in the Acheulian. However, since elephants, for example, contain huge quantities of fat year round (Ben-Dor et al. 2011), it might not make a difference which specific individual elephant is hunted and consumed. When elephants were not consumed any more in the AYCC and later, it made a whole lot of a difference which deer is being hunted in order to supply not only meet but fat, and thus new tracking and hunting capabilities took front stage. After hunting, specific butchering and transportation practices characterized the AYCC at Qesem Cave, and these had to be culturally transmitted as well. Last but not least, the habitual use of fire in the AYCC brought about a new set of knowledge and capabilities that had to do with the collection of firewood, the production and maintenance of fire and of course meat (and may be other foods) roasting and cooking as well. It is our contention, therefore, that new AYCC adaptations necessitated elaborate knowledge transmission mechanisms, different to a degree than the ones practiced during Acheulian times, and these mechanisms were supported by a new social milieu and based on a possible new discourse between experienced and inexperienced individuals within the group.

7.6 Endnote and Conclusions

> There must also have been "core" areas, or refugia, where long-term residence was possible during dry as well as moist episodes, because without such core area, regions that were inhabitable only intermittently could not have been colonized. …. In Southwest Asia, the Levant and western Turkey are obvious candidates…
>
> There were two particularly important archaeological developments in the Middle Pleistocene. The second was the emergence of big game hunting of prime adult ungulates as the main way of obtaining food. This is certainly evidenced in the Levant by 350 ka at Qesem Cave… If one adds the evidence of fire at Qesem, Schoningen and probably Gesher Benot Ya'aqov and locality I, Zhoukouian, cooking may be another Middle Pleistocene innovation indigenous to Eurasia (Dennell 2009, pp. 476–477).

We would like to start with a "tale of two caves," a tale that will elaborate on two components of our argument, caves and elephants. It is presented here in order to provide another perspective regarding the equifinality of our argument on the presence of elephants in Acheulian sites as opposed to their absence from AYCC sites. It is true that the Acheulian sites in the Levant that have produced significant elephant remains are open-air sites, while the AYCC sites that lack elephant remains are mostly cave sites, and thus the nature of the site might have played a role in prey animal representation (Speth 2012). While we cannot rule out such a possibility, we strongly believe that the fact that later Middle Paleolithic Mousterian open-air and cave sites in the Levant lack elephants altogether (Speth 2012) supports our argument regarding the disappearance of elephants from the human diet already ca. 400,000 years. However, we would like to present two Paleolithic cave sites where elephant remains were present, in order to demonstrate that the transportation of such large mammals to cave sites is possible and examples although few, do exist. Indeed the two caves are clearly unrelated to the Lower Paleolithic Levant, and are shortly mentioned here not as a direct analogy but in order to demonstrate that the use of elephants by humans in the Paleolithic was indeed significant, even if it necessitated transporting such enormous food items into cave sites.

The first example comes from Bolomor Cave in Spain (Blasco and Fernández Peris 2012). Bolomor Cave is located in Valencia at 100 m a.s.l. The stratigraphic sequence is divided into 17 levels, dated from ca. 350 to 121 ka. A wide range of animal species were processed and consumed by the

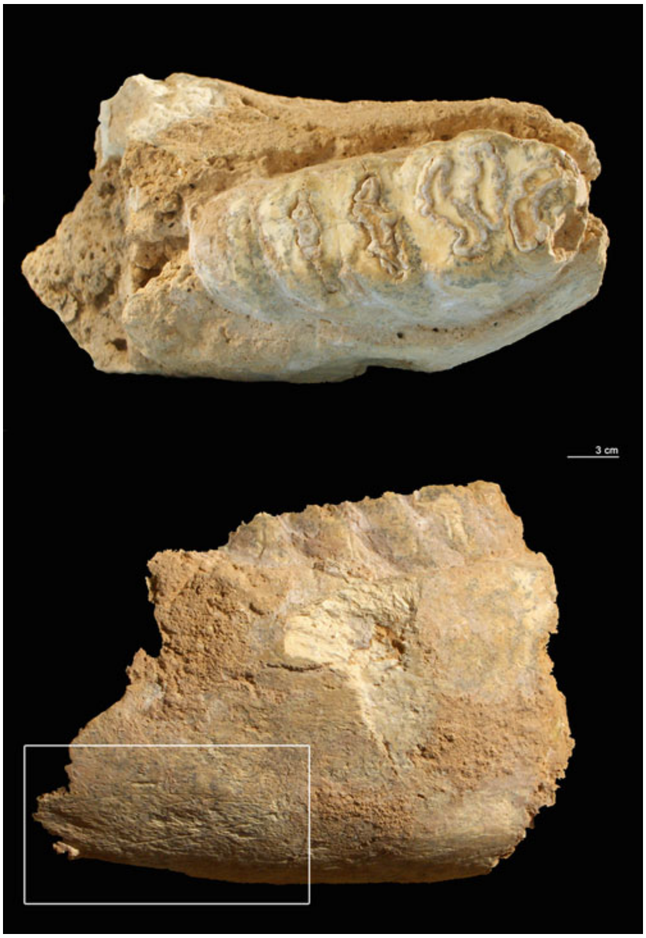


Fig. 7.11 Elephant mandible from level XII, Bolomor Cave, with cut marks. Courtesy Ruth Blasco

occupants of Bolomor, including large and small ungulates, as well as smaller taxa such as lagomorphs, tortoises and birds (Blasco and Fernández Peris 2012). The lithic technology is characterised by flake production, which is not typologically related to the peninsular Acheulean, a scarce presence of the Levallois technique and by lithic recycling. No handaxes were found and therefore, the Bolomor industry can be viewed as the first post-Acheulian industry of Western Europe in the second half of the Middle Pleistocene. Bolomor Cave shows clear evidence for the habitual use of fire documented from at least level XIII (MIS 7c). Elephant remains were identified at almost all levels of Bolomor, and are mostly represented by young individuals. A very interesting case of an elephant mandible with cut marks is of note (Fig. 7.11). It should be kept in mind that to reach Bolomor cave it would take a considerable effort since it necessitate a 100 m climb above the channel. Regardless of its accessibility, large mammals such as elephants were repeatedly brought up slope to the cave in order to be consumed. It is true that in the case of Bolomor Cave, behavioural innovations such as the habitual use of fire, recycling and a post-Acheulian lithic industriy appeared while elephants were still consumed. This reflects a different replacement model than the case of the AYCC in the Levant where we argue that the disappearance of elephants was the trigger to theses transformations. Moreover, in the case of Bolomor these innovations were carried out by members of the Neanderthal lineage (Arsuaga et al. 2012) although the circumstances for the appearance of this lineage in Europe are still far from being understood. One should keep in mind that the inhabitants of Bolomor Cave hunted, processed and ate a broad spectrum of animal species (from very small to very large-sized animals). In this case, the dependence on the environment is overcome by a behavior that facilitates access to a broad spectrum of prey and the practice of various subsistence strategies, the consumption of elephants being one of them. Diet, and changes in diet, might have played an important role in the appearance of post-Acheulian lifeways in the southern and western rims of the Iberian Peninsula as well. In our opinion Bolomor might represent another local example of cultural and perhaps biological transformation from Acheulian to post-Acheulian that has to be further investigated in years to come.

The second example comes from Ma'anshan site (Guizhoa, South China). The earlier of the two layers of the cave represents the later part of the Early Paleolithic (ca. 53 ka) while the later layer is assigned to the Chinese Late Paleolithic (ca. 30–20 ka) (Zhang et al. 2010). The occupants of the later layers of Ma'anshan Cave hunted mainly medium and small animals, while the occupants of the earlier layers tended to prey upon larger animals. In the later layers, hominins also made a more intensive use of the carcasses. It is of note that Rhinoceros and Stegodon (Class IV mammals, 1,000–3,000 kg) are represented by an NISP of 146 in the early layer as opposed to 40 in the later layer (Zhang et al. 2010, Table 4), and a significant decrease in the mean body size of the mammals from the earlier to the later phases was noted by the authors. It is interesting that Rhinoceros and Stegodon are represented mostly by cranial, carpal/tarsal, metapodial and phalangeal elements. This led the authors to suggest that "the bones of rhinos and elephants are exceptionally heavy, and hominins defleshed parts of the animals at the death site and took only some of the soft tissues back to the cave. It seems unlikely that these parts would be of nutritional interest to the hominins if they also had access to massive muscles of such large animals. Hence it is possible that these body parts were remnants of the carcasses still available at the time of encounter and still containing some food value. Because the head and foot parts are structurally complex, it is difficult to obtain all the nutrition from them in a short time, so the hunters may have chosen to take them back to camp for processing" (Zhang et al. 2010, p. 2073). Having said that, they also suggest that the evidence show that the earlier occupants of the cave were more likely to carry back marrow-rich limb bones, and they tended to abandon foot bones at kill sites. Moreover, Juvenile elephants were preferred in the upper layer. The authors suggest that "Juveniles were preferred, possibly because adults were too dangerous to hunt. One ethnoarchaeological study reports that the Liangula hunters of east Kenya who hunted elephants for meat (not for tusks), preferred to prey upon juveniles because their meat tasted better. However, adult elephant meat is consumed by a variety of African groups today, so 'taste' is not sufficient to explain the difference in prey age selection. Hominins at Ma'anshan probably preyed on juvenile S. orientalis because the calves were easier to kill, particularly if already stranded or separated from the mother or maternal herd" (Zhang et al. 2010, p. 2076). This note could also explain the preference for young elephants at Bolomor Cave and maybe also the possibly young adult elephant at Gesher Benot Ya'aqov (Goren-Inbar et al. 1994). On top of that, in the early layer, remains of adult elephants do exist and these were exceptionally large animals that represented one extreme of the prey body size range of animals consumed by the hominins at the cave. To conclude, the authors suggest that "Occupants of the upper layer in Ma'anshan cave hunted mainly medium-sized angulate prey. The hunters brought meaty parts of their prey back to the base camp, where they defleshed both limbs and ribs with equal energy, and probably were more likely to roast these parts than earlier hominins" (Zhang et al. 2010, p. 2076). The evidence from Ma'anshan cave strongly supports an argument in favor of the significant and constant role of elephants in the diet of the site's occupants. It demonstrates another case of repeatedly transporting elephant body parts into a cave site. Moreover, it might be seen as an additional case supporting a model of a declining use of elephants over time and their replacement by more intensive consumption of available smaller prey.

The two abovementioned examples lend support to our argument regarding the role of elephants in the human diet, as long as elephants are available. Another recent study by Fa et al. (2013) supports our model on the compensation needed when communities loose a significant source of calories. This study (Fa et al. 2013) presents changes in mammalian biomass and mean body mass of mammals over a period of 50,000 years in the Iberian peninsula, and illustrates the dramatic loss of the large mammalian fauna and how the rabbit has become a consistent substitute of the lost biomass throughout that period. They suggest that hunters that could shift their focus to rabbits and other smaller residual fauna once larger-bodied species decreased in numbers would have been able to persist.

To conclude, it is our contention that *Homo erectus* (*senso lato*) in the Levant was dependent on elephants (and especially their fat) for his survival. The disappearance of elephants from the Levant some 400,000 years ago coincides with the end of the Acheulian cultural complex and the appearance of a new and innovative local cultural complex—the Levantine Acheulo-Yabrudian. As is evident from the dental remains recently found at Qesem Cave, the hominins occupying this cave cannot be assigned to *H. erectus* but rather belong to a new hominin lineage, most similar to later Modern human populations in the region including the Skhul/Qafzeh and possibly Neanderthal populations. This hominin exhibits a new set of innovative behavioral and cultural traits. We suggest that the disappearance of the elephants created a need to hunt an increased number of smaller and faster animals to maintain an adequate fat content in the diet, and this was the evolutionary drive behind the emergence of the lighter, more agile, and cognitively capable new hominins in the Levant. We content that the changes in diet and hunting practices that followed the disappearance of elephants have necessarily led to a biological selection within the local Levantine Acheulian (*Homo erectus*) populations promoting those who were better adapted to a selective hunt of medium-sized mammals. In our opinion *Homo erectus* in the Levant must have been perfectly adapted to a diet in which the consumption of elephant fat and meat played a significant role. Acheulian hominins survived in the Levant for over a million years by (most probably) hunting and consuming elephants, as well as other game, however elephants were a constant component of their nutrition. Once elephants were no longer available in the Levant some 400 ka ago, the "rules" have changed in favor of more agile and cognitively capable individuals that were better in identifying prime-aged medium-sized mammals and hunting them in large numbers. These individuals that enjoyed no advantage while elephants were present became very useful and better adapted in the "post elephant" new circumstances and dietary needs and they are the ones who started the new hominin lineage. The need to hunt larger numbers of selected medium-sized individuals with high fat content might have encouraged new social relations based on new meat sharing practices. The habitual use of fire for roasting (and may be cooking) might be connected to the need to extract more calories from hunted meat and the new lithic technologies might have been aimed at a better manipulation of smaller game. The disappearance of a constant and primary food source that was used for over one million years in the Levant, the elephant, caused changes in diet, economy and society that triggered the evolutionary process that brought about the replacement of *Homo erectus* by a new hominin lineage and the Acheulian by a new cultural complex some 400,000 years ago. Our hypothesis is currently relevant to the specific case of the Levant however, its implications might shed new light on more general replacement scenarios. It was suggested in the past, for example, that Neanderthals were top-carnivores, highly dependent on the consumption of calories from megafauna, elephants and mammoths included (Geist 1981, 2001; Stewart 2007), and that the reduction in number of these prey animals might have played a role in Nenaderthal extinction. While such a model was only preliminary suggested, it should be thoroughly tested in the case of the replacement of Neanderthals by Modern Humans in Europe since in this case too, diet and changes in diet might have a pivotal role.

Acknowledgements The Qesem Cave excavation project is supported by the Israel Science Foundation, CARE Archaeological Foundation, Leakey Foundation, Wenner-Gren Foundation, Thyssen Foundation and the Dan David Foundation. We wish to thank our friends and colleagues J. Rosell, R. Blasco, G. Boschian, D., Saccà and M. Mussi for their kind assistance in providing information and photographs as well as fruitful discussions and thoughts. However, our thoughts and hypothesis presented in this paper remain our own responsibility.

References

Alperson-Afil N, Goren-Inbar N (2010) The Acheulian site of GesherBenot Ya'aqov volume II: ancient flames and controlled use of fire. Springer Science Business Media B.V, Dordrecht

Anzidei AP (2001) Tools from elephant bones at La Polledrara di Cecanibbio and Rebibbia-Casal de' Pazzi. In: Cavarretta G, Gioia P, Mussi M, Palombo MR (eds) Proceedings of the 1st international congress the World of Elephants. CNR, Roma

Anzidei AP, Bulgarelli GM, Catalano P, Cerilli E, Gallotti R, Lemorini C, Milli S, Palombo MR, Pantano W, Santucci E (2011) Ongoing research at the late Middle Pleistocene site of La Polledrara di Cecanibbio (central Italy), with emphasis on human–elephant relationships. Quat Int 255:171–187. doi:10.1016/j.quaint.2011.06.005

Arnold JE (2012) Detecting apprentices and innovators in the archaeological record: the shell bead- making industry of the Channel Islands. J Archaeol Method Theory 19:269–305

Arsuaga JL, Fernández Peris J, Gracia-Téllez A, Quam R, Carretero JM, Barciela González V, Sañudo P (2012) Fossil human remains from Bolomor Cave (Valencia, Spain). J Hum Evol 62:629–639

Aureli D, Contardi A, Giaccio B, Modesti V, Palombo MR, Rozzi R, Sposato A, Trucco F (2012) Straight-tusked elephants in the Middle Pleistocene of northern Latium: preliminary report on the Ficoncella site Tarquinia, Central Italy. Quat Int 255:29–35

Barkai R (2009) Comment on Sharon G Acheulian giant core technology: a worldwide perspective. Curr Anthropol 50(3):356–357

Barkai R, Gopher A (2009) Changing the face of the earth: human behavior at Sede Ilan, an extensive Lower-Middle Paleolithic quarry site in Israel. In: Adams B, Blades B (eds) Lithic materials and Paleolithic societies. Blackwell, Oxford

Barkai R, Gopher A (2011) Innovative human behavior between Acheulian and Mousterian: a view from Qesem Cave, Israel. In: Le Tensorer JM et al (eds) The Lower and Middle Palaeolithic in the Middle East and neighbouring regions. ERAUL, Liège

Barkai R, Gopher A, Lauritzen SE, Frumkin A (2003) Uranium series dates from Qesem Cave, Israel, and the end of the Lower Palaeolithic. Nature 423:977–979

Barkai R, Gopher A, Shimelmitz R (2005) Middle Pleistocene blade production in the Levant: an Amudian assemblage from Qesem Cave, Israel. Eur Prehist 3:39–74

Barkai R, Lemorini C, Shimelmitz R, Lev Z, Stiner M, Gopher A (2009) A blade for all seasons? Making and using Amudian blades at Qesem Cave, Israel. J Hum Evol 24:57–75

Barkai R, Lemorini C, Gopher A (2010) Palaeolithic cutlery 400,000–200,000 years ago: tiny meat-cutting tools from Qesem Cave, Israel. Antiquity 84:325

Barkai R, Solodenko N, Lemorini C (2013) An Amudian oddity: a giant biface from late Lower Paleolithic Qesem Cave in context. Tel-Aviv

Bar-Yosef O (1994) The Lower Paleolithic of the Near East. J World Prehist 8(3):211–265

Bar-Yosef O (2006) The known and unknown about the Acheulian. In: Goren-Inbar N, Sharon G (eds) Axe age: Acheulian tool-making from quarry to discard. Equinox, London

Bar-Yosef O, Belmaker M (2011) Early and Middle Pleistocene faunal and hominin dispersals through Southwestern Asia. Quat Sci Rev 30:1318–1337

Bar-Yosef O, Kuhn SL (1999) The big deal about blades: laminar technologies and human evolution. Am Anthropol 101(2):322–338

Beaumont PB (2011) The edge: more on fire-making by about 1.7 million years ago at Wonderwerk Cave in South Africa. Curr Anthropol 52(4):585–595

Ben-Dor M, Gopher A, Hershkovitz I, Barkai R (2011) Man the fat hunter: the demise of *Homo erectus* and the emergence of a new hominin lineage in the Middle Pleistocene (ca. 400 kyr) Levant. PLoS One 6(12):e28689

Bermúdes de Castro JL, Martinón-Torres M (2012) A new model for the evolution of the human Pleistocene populations of Europe. Quat Int 295:102–112

Berna F, Goldberg P, Horwitz LK, Brink J, Holt S, Bamford M, Chazan M (2012) Microstratigraphic evidence of in situ fire in the Acheulean strata of Wonderwerk Cave, Northern Cape Province, South Africa. Proc Natl Acad Sci USA 109:E1215–E1220

Beyen Y, Katoh S, WoldeGabriel G, Hart WK, Uto K, Sudo M, Kondo M, Hyodo M, Renne PR, Suwa G, Asfaw B (2013) The characteristics and chronology of the earliest Acheulian at Konso, Ethiopia. Proc Natl Acad Sci USA 110(5):1584–1591

Blasco R, Fernández Peris J (2012) A uniquely broad spectrum diet during the Middle Pleistocene at Bolomor Cave (Valencia, Spain). Quat Int 252:16–31

Blasco R, Rosell J, Domínguez-Rodrigo M, Lozano S, Pastó I, Riba D, Carbonell E (2013) Learning by heart: cultural patterns in the faunal processing sequence during the Middle Pleistocene. PLoS One 8(2):e55863

Blutron Jones N, Konner M (1998) !Kung knowledge of animal behavior. In: Lee RB, DeVore I (eds) Kalahari hunter-gatherers: studies of the !Kung San and their neighbors. Harvard University Press, Cambridge

Blutron Jones N, Marlowe F (2002) Selection for delayed maturity: does it take 20 years to learn to hunt and gather? Hum Nat 13(2):199–238

Boaretto E, Barkai R, Gopher A, Berna F, Weiner S (2009) Specialized flint procurement strategies for hand axes, scrapers and blades in the late Lower Paleolithic: a 10Be study at Qesem Cave, Israel. J Hum Evol 24(1):1–12

Boschian G, Saccà D (2010) Ambiguities in human and elephant interactions? Stories of bones, sand and water from Castel di Guido (Italy). Quat Int 214:3–16

Bourguignon L (2001) Apports de l'expérimentation et de l'analyse techno-morpho-fonctionnelle à la reconnaissance des processus d'aménagement de la retouche Quina. In: Bourguignon L, Ortega I, Frère-Sautot MC (eds) Préhistoire et approche expérimentale, Préhistoires n° 5. Monique Mergoil Editions, Montagnac

Braun IM, Palombo MR (2012) Mammuthus primigenius in the cave and portable art: an overview with a short account on the elephant fossil record in Southern Europe during the last glacial. Quat Int 276–277:61–76

Bunn HT (1981) Archaeological evidence for meat-eating by Plio-Pleistocene hominids from Koobi Fora and Olduvai Gorge. Nature 291:574–577

Bunn HT (2006) Meat made us human. In: Ungar P (ed) Evolution of the human diet: the known, the unknown, and the unknowable. Oxford University Press, Oxford, pp 191–211

Bunn HT, Ezzo JA (1993) Hunting and scavenging by Plio-Pleistocene hominids: nutritional constraints, archaeological patterns, and behavioral implications. J Archaeol Sci 20(4):365–398

Bunn HT, Kroll E (1986) Systematic butchery by Plio/Pleistocene hominids at Olduvai Gorge, Tanzania (and comments and reply). Curr Anthropol 27:431–452

Carmody RN, Wrangham RW (2009) The energetic significance of cooking. J Hum Evol 57:379–391

Claud E, Soressi M, Jaubert J, Hublin J-J (2012) Étude tracéologique de l'outillage moustérien de type Quina du bonebed de Chez-Pinaud à Jonzac (Charente-Maritime). Nouveaux éléments en faveur d'un site de boucherie et de traitement des peaux. Gallia Préhistoire 54:3–32

Clottes J (2013) Why did they draw in those caves? Time Mind 6(1):7–14

Copeland L (1983) The Amudian Beach Industry at Abri Zumoffen. In: Roe DA (ed) Adlun in the Stone Age, vol 159, BAR international series. British Archaeological Reports, Oxford

Copeland L (2000) Yabrudian and related industries: the state of research in 1996. In: Ronen A, Weinstein-Evron M (eds) Toward modern humans: Yabrudian and Micoquian, 400–50 kyears ago, vol 850, BAR international series. Archaeopress, Oxford

Costa SJ (2010) A geometric morphometric assessment of plan shape in bone and stone Acheulean bifaces from the Middle Pleistocene site of Castel di Guido, Latium, Italy. In: Lycett SJ, Chauhan PR (eds) New perspectives on old stones: analytical approaches to Paleolithic technologies. Springer, New York, pp 23–41

Dennell R (2009) The Palaeolithic settlement of Asia. Cambridge University Press, Cambridge

Domínguez-Rodrigo M, Pickering TR, Díez-Martín F, Mabulla A, Musiba C, Trancho G, Baquedano E, Bunn HT, Barboni D, Santonja M, Uribelarrea D, Ashley GM, Martínez-Ávila MS, Barba R, Gidna A, Yravedra J, Arriaza M (2012) Earliest porotic hyperostosis on a 1.5-million-year-old hominin, Olduvai Gorge, Tanzania. PLoS One 7(10):e46414

Echassoux A (2012) Comportements de subsistance et modifications osseuses à l'aube de l'Acheuléen à Konso, Éthiopie. L'Anthropol 116:291–320

Endicott P, Ho S, Stringer C (2010) Using genetic evidence to evaluate four palaeoanthropological hypotheses for the timing of Neanderthal and modern human origins. J Hum Evol 59:87–95

Eren MI, Bradley AB, Sampson CG (2011) Middle Paleolithic skill level and the individual knapper: an experiment. Am Antiquity 76(2):229–251

Fa JE, Stewart JR, Lluís L, Mario Vargas J (2013) Rabbits and hominin survival in Iberia. J Hum Evol 64:233–241

Ferguson J (2008) The when, where, and how of novices in craft production. J Archaeol Method Theory 15:51–67

Fernández Peris J, González VB, Blasco R, Cuartero F, Fluck H, Sañudo P, Verdasco C (2010) The earliest evidence of hearths in Southern Europe: the case of Bolomor Cave (Valencia, Spain). Quat Int 247:267–277

Finaly N (1997) Kid knapping: the missing children in lithic analysis. In: Moore J, Scott E (eds) Invisible people and processes: writing gender and childhood into European Archaeology. Leicester University Press, London

Fisher JW Jr (1993) Foragers and farmers: material expressions of interaction at elephant processing sites in the Ituri Forest, Zaire. In: Hudson J (ed) From bones to behavior: ethnoarchaeological and experimental contributions to the interpretation of faunal remains, vol 21, Carbondale: Center for Archaeological Investigations, Occasional Paper. Southern Illinois University, Carbondale

Fisher JW Jr (2001) Elephant butchery practices in the lturi forest, Democratic Republic of the Congo, and their relevance for interpreting human activities at prehistoric proboscidean sites. In: West D (ed) Proceedings of the international conference on Mammoth site studies publications in anthropology, vol 22, University of Kansas, Lawrence

Freidline SE, Gunz P, Janković I, Harvati K, Hublin JJ (2012) A comprehensive morphometric analysis of the frontal and zygomatic bone of the Zuttiyeh fossil from Israel. J Hum Evol 62:225–241

Frumkin A, Karkanas P, Bar-Matthews M, Barkai R, Gopher A, Shahack-Gross R, Vaks A (2009) Gravitational deformations and filling of aging caves: the example of Qesem Cave karst system, Israel. Geomorphol 106:154–164

Garrod DAE (1956) Acheuleo-Jabrudian et Pre-Aurignacian de la Grotte du Taboun (Mont Carmel): etude stratigraphique et chronologique. Quaternaria 3:39–59

Garrod DAE (1970) Pre-Aurignacian and Amudian: a comparative study of the earliest blade industries of the Near East. In: K G, Schütrumpf R, Schabedissen H (eds) Frühe Menschheit und Umwelt. Böhlau, Köln

Garrod DAE, Bate DMA (1937) The stone age of Mount Carmel, vol 1. Oxford University Press, Oxford

Garrod DAE, Kirkbride D (1961) Excavation of the Abri Zumffen, a paleolithic rock-shelter near Adlun, South Lebanon, 1958. Bull Mus Beyrouth XVI:7–48

Gaudzinski S, Turner E, Anzidei AP, Alvarez-Fernández E, Arroyo-Cabrales J, Cinq-Mars J, Dobosi VT, Hannus A, Johnson E, Münzel SC, Scheer A, Villa P (2005) The use of proboscidean remains in every-day Palaeolithic life. Quat Int 126–128: 179–194

Geist V (1981) Neanderthal the hunter. Nat History 90(1):26–36

Geist V (2001) Of reindeer and man, modern and Neanderthal: a creation story founded on a historic perspective on how to conserve wildlife, woodland caribou in particular. Rangifer 23(5):57–63

Geribas N, Mosquera M, Verges JM (2010) What novice knappers have to learn to become expert stone toolmakers. J Archaeol Sci 37:2857–2870

Gissis I, Bar-Yosef O (1974) New excavations in Zuttiyeh Cave, Wadi Amud, Israel. Paleorient 5:175–180

Gopehr A, Ayalon A, Bar-Matthews M, Barkai R, Frumkin A, Karkanas P, Shahack-Gross R (2010) The chronology of the late Lower Paleolithic in the Levant: U series dates of speleothems from Middle Pleistocene Qesem Cave, Israel. Quat Geochron 5:644–656

Gopher A, Barkai R (2011) Sitting on the tailing piles: creating extraction landscapes in Middle Pleistocene quarry complexes in the Levant. World Archaeol 43(2):211–229

Gopher A, Barkai R, Shimelmitz R, Khalaily M, Lemorini C, Hershkovitz I, Stiner M (2005) Qesem cave: an Amudian site in central Israel. J Israel Prehist Soc 35:69–92

Goren-Inbar N (2011) Culture and cognition in the Acheulian industry: a case study from Gesher Benot Yaakov. Philos Trans R Soc B 366:1038–1049

Goren-Inbar N, Belfer-Cohen A (1998) The technological abilities of the Levantine Mousterians: cultural and mental capacities. In: Akazawa T, Aoki K, Bar-Yosef O (eds) Neandertals and modern human in Western Asia. Plenum, New York

Goren-Inbar N, Sharon G (2006) Invisible handaxes and visible Acheulian biface technology at Gesher Benot Ya'aqov, Israel. In: Goren-Inbar N, Sharon G (eds) Axe age: Acheulian tool-making from quarry to discard. Equinox, London

Goren-Inbar N, Lister A, Werker E, Chech M (1994) A butchered elephant skull and associated artifacts from the Acheulian site of Gesher Benot Ya'aqov, Israel. Paléorient 20:99–112

Goren-Inbar N, Alperson N, Kislev ME, Simchoni O, Melamed Y et al (2004) Evidence of hominin control of fire at Gesher Benot Yaaqov, Israel. Science 304(5671):725–727

Gowlett JAJ (2010) Firing up the social brain. In: Dunbar R, Gamble C, Gowlett JAJ (eds) Social brain, distributed mind. Oxford University Press, Oxford

Grimm L (2000) Apprentice flintknapping: relating material culture and social practice in the Upper Paleolithic. In: Sofaer Derevenski J (ed) Children and material culture. Routledge, London

Hallos J (2005) "15 minutes of fame": exploring the temporal dimension of Middle Pleistocene lithic technology. J Hum Evol 49(155):179

Haynes G (1987) Proboscidean die-offs and die-out: age profiles in fossil collections. J Archaeol Sci 14:659–668

Haynes G, Krasinski KE (2010) Taphonomic fieldwork in southern Africa and its application in studies of the earliest peopling of North America. J Taphonomy 8(2–3):181–202

Hershkovitz I, Smith P, Sarig R, Quam R, Rodríguez L, García R, Arsuaga JL, Barkai R, Gopher A (2011) Middle Pleistocene dental remains from Qesem Cave, Israel. Am J Phys Anthropol 144:575–592

Hewlett BS, Lamb ME (eds) (2003) Hunter-gatherer childhoods: evolutionary, developmental and cultural perspectives. Transaction Books, New Brunswick

Hewlett BS, Fouts H, Boyette A, Hewlett BL (2011) Social learning among Congo Basin hunter-gatherers. Roy Soc B 366:1168–1178

Hogberg A (2008) Playing with flint: tracing a child's imitation of adult work in lithic assemblages. J Arch Method Theory 15:112–131

Holen SR (2006) Taphonomy of two last glacial maximum mammoth sites in the central Great Plains of North America: a preliminary report on La Sena and Lovewell. Quat Int 142:30–43

Holen K, Holen SR (2007) An elephant bone breakage experiment in Tanzania, East Africa. Great Plains Paleoindian Archaeol 1:5–6

Horsholm AF (1990) A Late Paleolithic "school" of flint- knapping at Trollesgave, Denmark. Acta Archaeol 60:33–49

Hovers E (2009) Learning from mistakes: flaking accidents and knapping skills in the assemblage of A. L. 894 (Hadar, Ethiopia). In: Schick K, Toth N (eds) The cutting edge: new approaches to the archaeology of human origins. Stone Age Institute, Gosport

Janmart J (1952) Eleohant hunting as practiced by Tee Congo Pygmies. Am Anthropol 54(1):146–147

Jelinek AJ (1982) The Tabun Cave and Paleolithic man in the Levant. Science 216:1369–1375

Jelinek AJ (1990) The Amudian in the context of the Mugharan tradition at the Tabun Cave (Mount Carmel), Israel. In: Mellars P (ed) The emergence of modern humans. Cornell University Press, Ithaca

Johnson CR, McBrearty S (2010) 500,000 year old blades from the Kapthurin Formation, Kenya. J Hum Evol 58:193–200

Kamp KA (2001a) Where have all the children gone?: the archaeology of childhood. J Archaeol Method Theory 8(1):1–34

Kamp KA (2001b) Prehistoric children working and playing: a southwestern case study in learning ceramics. J Anthropol Res 57(4):427–450

Kaplan H, Hill K, Lancaster J, Hurtado AM (2000) A theory of human life history evolution: diet, intelligence, and longevity. Evol Anthropol 9(4):156–185

Kaplan H, Gangestad S, Gurven M, Lancaster J, Mueller T et al (2007) The evolution of diet, brain and life history among primates and humans. In: Roebroeks W (ed) Guts and brains an integrative approach to the hominin record. Leiden University Press, Leiden

Karkanas P, Shahack-Gross R, Ayalon A, Bar-Matthews M, Barkai R, Frumkin A, Gopher A, Stiner MC (2007) Evidence for habitual use of fire at the end of the lower Paleolithic: site formation processes at Qesem Cave, Israel. J Hum Evol 53:197–212

Keith A (1927) A report on the Galilee skull. In: Turville-Pétre F (ed) Researches in Prehistoric Galilee. Council of the British School of Archaeology in Jerusalem, London, pp 1925–1926

Keith K (2006) Childhood learning and the distribution of knowledge in foraging societies. In: Baxter JE (ed) Children in action: perspectives on the archaeology of childhood. American Anthropological Association, Berkeley

Klein RG (1988) The archaeological significance of animal bones from Acheulean sites in southern Africa. Afr Archaeol Rev 6:3–25

Le Cabec A, Gunz P, Kupczik K, Braga J, Hublin JJ (2012) Anterior tooth root morphology and size in Neanderthals: taxonomic and functional implications. J Hum Evol 64:169–193

Lemorini C, Gopher A, Shimelmitz R, Stiner M, Barkai R (2006) Use-wear analysis of an Amudian laminar assemblage from Acheuleo-Yabrudian Qesem Cave, Israel. J Archaeol Sci 33:921–934

Lillehammer G (1989) A child is born. The child's world in an archaeological perspective. Norw Archaeol Rev 22(2):89–105

Liu W, Schepartz LA, Xing S, Miller-Antonio S, Wu X, Trinkaus E, Martinón-Torres M (2013) Late Middle Pleistocene hominin teeth from Panxian Dadong, South China. J Hum Evol 64:337–355

Loshe JC (2011) Step by step: the influence of reduction sequence models on understanding learning and skill transmission. Lithic Tecnnol 36(2):97–108

Lycett SJ, Gowlett JAJ (2008) On questions surrounding the Acheulian "tradition". World Archaeol 40(3):295–315

MacDonald K (2007) Cross-cultural comparison of learning in human hunting. Hum Nat 18:386–402

Machin A (2009) The role of the individual agent in Acheulian biface variability: a multi-factorial model. J Soc Archaeol 9:35–58

Marks S (1976) Large mammals and a brave people. University of Washington Press, Seattle

Maul L, Smith K, Barkai R, Barash A, Karkanas P, Shahack-Gross R, Gopher A (2011) Of men and mice at Middle Pleistocene Qesem Cave, Israel: small vertebrates, environment and biostratigraphy. J Hum Evol 60:464–480

Mendez FL, Krahn T, Schrack B, Krahn AM, Veeramah KR, Woerner AE, Hammer MF (2013) An African American paternal lineage adds an extremely ancient root to the human Y chromosome phylogenetic tree. Am J Hum Genet 92:1–6

Mercier N, Valladas H, Falgueres C, Shao Q, Gopher A, Barkai R, Bahain JJ, Vialettes L, Joron JL, Reyss JK (2013, in press) New datings of Amudian layers at Qesem Cave (Israel): results of TL applied to burnt flints and ESR/U-series to teeth. J Archaeol Sci 40:3011–3020

Milton K (2003) The critical role played by animal source foods in human (Homo) evolution. J Nutrition 133(11):3886S–3892S

Monigal K (2001) Lower and Middle Paleolithic blade industries and the dawn of the Upper Paleolithic in the Levant. Archaeol Ethnol Anthropol Eurasia 1(5):11–21

Monigal K (2002) The Levantine Leptolithic: blade production from the Lower Paleolithic to the dawn of the upper Paleolithic. Dissertation, Southern Methodist University, Dallas

Morin E (2007) Fat composition and Nunamiut decision-making: a new look at the marrow and bone grease indices. J Archaeol Sci 34(1):69–82

Mussi M (2005) Hombres y Elefantes en las latitudes medias: una larga convivencia (con la colaboración de: AP Anzidei. G Boschian, F Martini, P Mazza, M Piperno). In: Santonja Gomez M, Pérez-González A (eds) Los Yacimientos Paleoliticos de Ambrona y Torralba, Zona Arqueológica, vol 5. Museo Arqueológico Regional, Madrid, pp 396–417

Nishiaki Y, Kanjo Y, Muhesen S, Akazawa T (2011) Recent progress in Lower and Middle Palaeolithic research at Dederiyeh Cave, Northwest Syria. In: Le Tensorer JM, Jagher R, Otte M (eds) The Lower and Middle Palaeolithic in the Middle East and neighboring regions. ERAUL, Liege

Nonaka T, Bril B, Rein R (2010) How do stone knappers predict and control the outcome of flaking? Implications for understanding early stone tool technology. J Hum Evol 59:155–167

Nowell A (2010) Defining behavioral modernity in the context of Neandertal and anatomically modern human populations. Annu Rev Anthropol 39:437–452

Nowell A, White M (2010) Growing up in the Middle Pleistocene: life history strategies and their relationship to Acheulian Industries. In: Nowell A, Davidson L (eds) Stone tools and the evolution of human cognition. University Press of Colorado, Boulder, pp 67–82

Pante MC (2012) The larger mammal fossil assemblage from JK2, Bed III, Olduvai Gorge, Tanzania: implications for the feeding behavior of *Homo erectus*. J Hum Evol 64:68–82

Pigeot N (1990) Technical and social actors: flintknapping specialist and apperentices at Magdalenian Ettiolles. Archaeol Rev Cambridge 9(1):126–141

Psouni E, Janke A, Garwicz M (2012) Impact of carnivory on human development and evolution revealed by a new unifying model of weaning in mammals. PLoS One 7(4):e32452

Rabinovich R, Biton R (2011) The Early-Middle Pleistocene faunal assemblages of Gesher Benot Ya'aqov: inter-site variability. J Hum Evol 60:357–374

Rabinovich R, Gaudzinski-Windheuser S, Goren-Inbar N (2008) Systematic butchering of fallow deer (Dama) at the early Middle Pleistocene Acheulian site of Gesher Benot Ya 'aqov (Israel). J Hum Evol 54(1):134–149

Rabinovich R, Ackermann O, Aladjem E, Barkai R, Biton R, Milevski I, Solodenko N, Marder O (2012) Elephants at the Middle Pleistocene Acheulian open-air site of Revadim quarry. Quat Int 276–277:183–197

Rink WJ, Mercier N, Mihalović D, Morley MW, Thompson JW, Roksandic M (2013) New radiometric ages from the BH-1 hominin from Balanica (Serbia): implications for understanding the role of the Balkans in Middle Pleistocene human evolution. PLoS One 8(2):e54608. doi:doi:10.1371

Roebroeks W, Villa P (2011) On the earliest evidence for habitual use of fire in Europe. Proc Natl Acad Sci USA 108(13):5209–5214

Rust A (1950) Die Hohlenfunde von Jabrud (Syrien). Karl Wachholtz, Neumunster

Saccà D (2012a) Taphonomy of Palaeoloxodon antiquus at Castel di Guido (Rome, Italy): Proboscidean carcass exploitation in the Lower Palaeolithic. Quat Int 226–227:27–41

Saccà D (2012b) L'industria ossea di Castel di Guido (Roma): analisi tafonomica di bifacciali e strumenti poco elaborati. Rivista di Scienze Preistoriche LXII:13–32

Sahnouni M, Rosell J, van der Made J, Vergès JM, Ollé A, Kandi N, Medig M (2013) The first evidence of cut marks and usewear traces from the Plio-Pleistocene locality of El-Kherba (Ain Hanech), Algeria: implications for early hominin subsistence activities circa 1.8 Ma. J Hum Evol 64(2):137–150

Segre A, Ascenzi A (1984) Fontana Ranuccio: Italy's earliest Middle Pleistocene hominid site. Curr Anthropol 25:230–233

Sharon G (2009) Acheulian giant-core technology. Curr Anthropol 50(3):335–367

Sharon G (2010) Large flake Acheulian. Quat Int 223–224:226–233

Shimelmitz R, Gopher A, Barkai R (2011) Systematic blade production at late Lower Paleolithic (400–200 kyr) Qesem Cave, Israel. J Hum Evol 61:458–479

Shipman P, Rose J (1983) Early hominid hunting, butchering and carcass-processing behaviors: approches to the fossil record. J Anthropol Archaeol 2:57–98

Shipman P, Walker A (1989) The costs of becoming a predator. J Hum Evol 18(4):373–392

Shipton C (2010) Imitation and shared intentionality in the Acheulean. Cam Archaeol J 20(2):197–210

Shmookler L (1983) Masloukh revisited: the Amudian layers of the coastal site in Lebanon. Unpublished manuscript, Department of Anthropology, Columbia University, New York

Skinner JH (1970) El Masloukh: a Yabrudian site in Lebanon. Bull Mus Beyrouth XXIII:143–172

Smith KT, Maul LC, Barkai R, Gopher A (2013) To catch a chameleon, or actualism vs. natural history in the taphonomy of the microvertebrate fraction at Qesem Cave, Israel. J Archaeol Sci 40(8):3326–3339

Somel M, Liu X, Khaitobich P (2013) Human brain evolution: transcripts, metabolites and their regulators. Nat Rev Neurosci 14:112–127

Sorensen FS (2009) The identification of children's flintknapping products in Mesolithic Scandinavia. In: Mesolithic horizons: papers presented at the seventh international conference on the Mesolithic in Europe, Belfast 2005

Speth JD (2012) Middle Palaeolithic subsistence in the Near East: zooarchaeological perspectives – past, present and future. Before Farm 2012/2:1–45

Stanford D, Bonnichsen R, Morlan RE (1981) The Ginsberg experiment: modern and prehistoric evidence of a bone-flaking technology. Science 212:438–440

Steinhart EI (2000) Elephant hunting in 19th-century Kenya: Kamba society and ecology in transformation. Int J Afr Hist Studies 33(2):335–349

Stewart JR (2007) Neanderthal extinction as part of the faunal change in Europe during oxygen isotope stage 3. Acta Zoologica Cracoviensia 50A(1–2):93–124

Stiner M, Gopher A, Barkai R (2009) Cooperative hunting and meat sharing 400–200 kya at Qesem Cave, Israel. Proc Natl Acad Sci USA 106:13207–13212

Stiner M, Gopher A, Barkai R (2011) Hearth-side socioeconomics, hunting and paleoecology during the late Lower Paleolithic at Qesem Cave, Israel. J Hum Evol 60:213–233

Stout D (2005) The social and cultural context of stone-knapping skill acquisition. In: Roux V, Bril B (eds) Stone knapping: the necessary conditions for a uniquely hominin behaviour. MacDonald Institute for Archaeological Research, Cambridge

Stout D, Passingham R, Frith C, Apel J, Chaminade T (2011) Technology, expertise and social cognition in human evolution. Eur J Neurosci 33:1328–1338

Tryon CA, McBrearty S, Texier PJ (2006) Levallois lithic technology from the Kapthurin Formation, Kenya: Acheulian origin and Middle Stone Age diversity. Afr Archaeol Rev 22(4): 199–229

Turville-Petre F (1927) Researches in prehistoric Galilee (1925–1926). Bull British School of Archaeology in Jerusalem XIV:119

Tyron CA (2006) "Early" Middle Stone Age lithic technology of the Kapthurin formation (Kenya). Curr Anthropol 47:367–375

Verri G, Barkai R, Bordeanu C, Hass M, Kaufman A, Kubik P, Montanari E, Paul M, Ronen A, Weiner S, Boaretto E (2004) Flint mining in prehistory record by in situ produced cosmogenic 10Be. Proc Natl Acad Sci USA 101(21):780–7884

Verri G, Barkai R, Gopher A, Hass M, Kubik P, Paul M, Ronen A, Weiner S, Boaretto E (2005) Flint procurement strategies in the late Lower Palaeolithic record by in situ produced cosmogenic 10Be in Tabun and Qesem Caves (Israel). J Archaeol Sci 32:207–213

Villa P, Soto E, Santonja M, Pérez-Gonzáles A, Mora R, Parcerisas J, Sesé C (2005) New data from Ambrona; closing the hunting versus scavenging debate. Quat Int 126–128:223–250

Vishnyatsky LB (2000) The Pre-Aurignacian and Amudian as intra-Yabrudian-Episode. In: Ronen A, Weinstein-Evron M (eds) Toward modern humans: Yabrudian and Micoquian, 400-50 k years ago, vol 850, BAR international series. Archaeo, Oxford

Waters MR, Stafford TW Jr, McDonald HG, Gustafson C, Rasmussen M, Cappellini E, Willerslev E (2011) Pre-Clovis mastodon hunting 13,800 years ago at the Manis site, Washington. Science 334(6054):351–353

Wenban-Smith FF, Allen P, Bates MR, Parfitt SA, Preece RC, Steward JR, Turner C, Whitaker JE (2006) The Clactonian elephant butchery site at Southfleet Road, Ebbsfleet, UK. J Quat Sci 21(5):471–483

White M, Ashton N, Scott B (2011) The emergence, diversity and significance of mode 3 (prepared core) technologies. Dev Quat Sci 14:53–65

Wilkins J, Chazan M (2012) Blade production 500 thousand years ago at Kathu Pan 1, South Africa: support for a multiple origins hypothesis for early Middle Pleistocene blade technology. J Archaeol Sci 39(6):1883–1990

Wilkins J, Pollarolo L, Kuman K (2010) Prepared core reduction at the site of Kudu Koppie in northern South Africa: temporal patterns across the earlier and Middle Stone Age boundary. J Archaeol Sci 37(6):1279–1292

Winton V (2005) An investigation of knapping-skill development in the manufacture of Palaeolithic Handaxes. In: Roux V, Bril B (eds)

Stone knapping: the necessary conditions for a uniquely hominin behavior. Cambridge University Press, Cambridge

Wiseman MF (1993) Lithic blade elements from the southern levant: a diachronic view of changing technology and design process. J Israel Prehist Soc 25:13–102

Wrangham R, Carmody RN (2010) Human adaptation to the control of fire. Evol Anthropol 19(5):187–199

Wrangham RW, Jones JH, Laden G, Pilbeam D, Conklin-Brittain N (1999) The raw and the stolen: cooking and the ecology of human origins. Curr Anthropol 40(5):567–594

Yravedra J, Dominguez-Rodrigo M, Santonja M, Perz-Gonzalez A, Panera J, Rubio-Jara S, Baquedano E (2010) Cut marks on the middle Pleistocene elephant carcass of Aridos 2 (Madrid, Spain). J Archaeol Sci 37:2469–2476

Yravedra J, Rubio-Jara S, Panera J, Uribelarrea D, Pérez-González A (2011) Elephants and subsistence. Evidence of the human exploitation of extremely large mammal bones from the middle Palaeolithic site of PRERESA (Madrid, Spain). J Archaeol Sci 39:1063–1071

Yravedra J, Rubio-Jara S, Panera J, Uribelarrea D, Pérez-González A (2012). Elephants and subsistence. Evidence of the human exploitation of extremely large mammal bones from the middle Palaeolithic site of PRERESA (Madrid, Spain). J Archaeol Sci 39(4):1063–1071

Zeitoun V (2001) The taxonomical position of the skull of Zuttiyeh. CR Acad Sci Ser IIa Sci Terre Planets 332:521–525

Zhang Y, Stiner M, Dennel R, Wang C, Zhang S, Gao X (2010) Zooarchaeological perspectives on the Chinese early and late Paleolithic from the Ma'anshan site (Guizhoa, South China). J Archaeol Sci 37:2066–2077

Part II

Learning Behaviors in Prehistoric and Modern Hunter-Gatherers

The Evolutionary Development of Learning and Teaching Strategies in Human Societies

8

Hideaki Terashima

Abstract

The characteristics of learning behavior of modern hunter-gatherers are investigated in terms of evolutionary perspectives. Hunter-gatherer children have a long childhood compared with other animals and other human groups. During childhood they can learn knowledge and skills that they need to pursue foraging activities chiefly via social learning while participating and playing in play groups. Without formal school education or teaching, hunter-gatherer children are able to enjoy autonomous learning which leads to flexible and innovative behavior in adulthood. Hunter-gatherers engage in education as a cultural institution that is unique to humans: a socio-cultural interaction within a framework of intention and expectation, belief and trust between the learner and the teacher. This teaching relationship is in contrast to the biologically established teaching relationship such as natural pedagogy. After the onset of adolescence, young people expand their range of acitivities. Sometimes they visit distant relatives to learn new things away from their own people. This interconnectivity between social groups brings about opportunities for the exchange of goods and ideas that makes it possible for innovations to be more rapidly transmitted from group to group. Social organization, cognitive development, and bio-ecological fundamentals in the hunting and gathering way of life seem to have contributed all together to enhance human learning capacity.

Keywords

Social learning • Teaching • Innovation • Autonomy • Children • Hunting and gathering

8.1 Introduction

As a team of cultural and biological anthropologists and developmental psychologists participating in the RNMH project we aim to understand the characteristics of learning behavior and learning strategies of modern hunter-gatherers through fieldwork to obtain clues as to why Neanderthals were replaced by modern humans. It is a difficult task to compare the learning capacity between modern humans and Neanderthals as there is quite limited direct evidence that would show how Neanderthals learned knowledge and skills. One of the scarce examples is a workplace in a cave where Neanderthals were supposed to have made stone tools (Pigeot 1990; Hovers et al. 2011). Although it is apparent that we have to depend much on speculation, it is important to get a feel for how modern humans learn generally to understand the difference in learning ability between Neanderthals and modern humans.

We have chosen the following three points as main fields of research: (1) the hunting and gathering way of life, (2) children and childhood, and (3) play activities. These points were chosen based on the following ideas: First, we need to

H. Terashima (✉)
Faculty of Humanities and Sciences, Kobe Gakuin University, 518 Arise, Ikawadani-cho, Nishi-ku, Kobe 651-2180, Japan
e-mail: terasima@human.kobegakuin.ac.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_8,

explore how and what people learn in the hunting and gathering lifestyle that was the sole lifestyle of humans during the replacement process. Second, childhood is the most critical period for learning; not only to obtain knowledge and skills for daily life but also to establish a foundation for the later development of innovative behavior. Third, in a society without formal schooling, children learn mainly through daily social activities, specifically by playing in play groups.

8.2 Contemporary Hunter-Gatherers

8.2.1 Hunter-Gatherers in This Study

We chose to conduct our research study with hunter-gatherers living in a variety of environmental settings. We are working with African pygmy hunter-gatherers in the tropical rainforest (the Aka, the Baka, the Mbuti and the Efe), Bushmen groups in the arid savanna (the /Gwi and the //Gana,), Australian aborigines (the Yolngu in Arnhem land and the Yuendumu (the Warlpiri) in the Central Desert), and the Inuit in Arctic Canada (Fig. 8.1). Considering the variety of natural environments where these groups live, it is a wonder that we find so many similarities in their social organization, social relations, and social values. It is evident that the hunting and gathering way of life has been a very adaptive subsistence strategy during human evolution. Although the number of hunter-gatherers today has seriously diminished and many of them rely on subsistence activities other than hunting and gathering, hunter-gatherers have thrived into this twenty-first century without losing their vitality and unique characteristics.

Edwin N. Wilmsen argues that Bushmen have been marginalized and systematically excluded from the larger regional political economy. They have lost their traditional lifestyle and forced to live as the lowest class of society (Wilmsen 1989). It might be so in some cases, but not all. The hunter-gatherers we have studied so far are full of vitality and very positive about their lives (Woodburn 1988; Maruyama 2010). Some of them are recognized as the oldest genetic stock among human populations on the Earth (Chen et al. 2000). Their lifestyle has been the oldest adaptation to the environment and is still present and functioning even in very tough environments for human life such as the Arctic and the Kalahari semi-desert.

Although contemporary hunter-gatherers have been experiencing serious modifications to their lifestyle such as sedetalization due to control by the government and global-scale social changes, the following have been recoginized as general social and ecological characteristics of recent hunter-gatherers:

1. Most hunter-gatherers live in nomadic small groups called bands consisting of a few people to some dozens of families with fluid membership. People are usually related by various kinship bonds.
2. The band members have certain rights over a piece of land (hunting and gathering ground) where they can move freely all year round as they forage for food and other resources. It is usually called "territory" by anthropologists after Radcliff-Brown (1930/31), but usually access to the

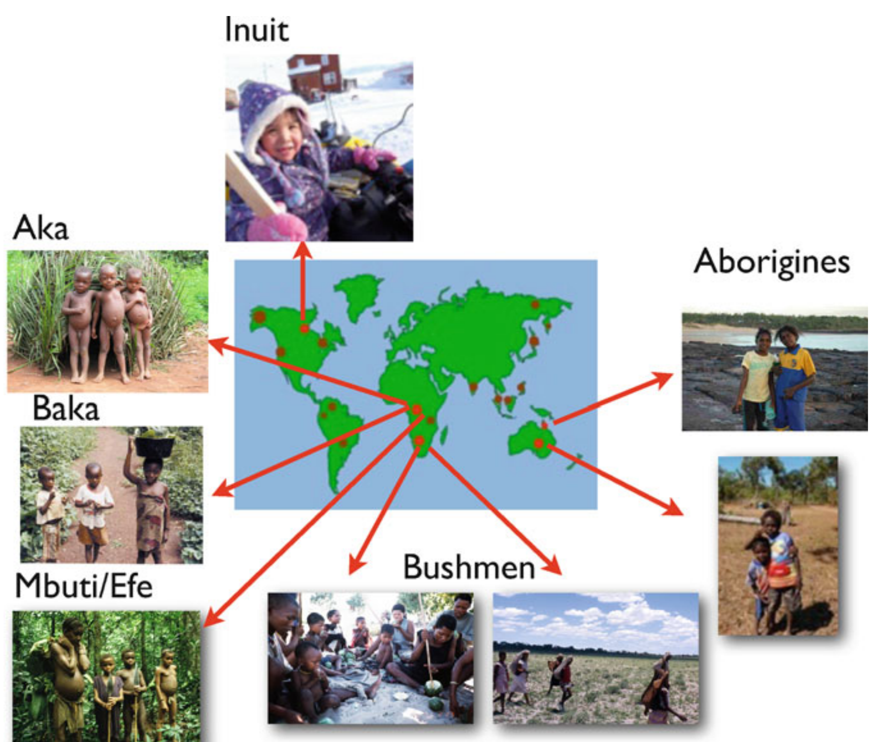


Fig. 8.1 Hunter-gatherers in this study. Photos are courtesy of Keiichi Omura (Inuit), Bonnie L. Hewlett (Aka), Nobutaka Kamei (Baka), Bushmen (Kaoru Imamura) and Sachiko Kubota (Australia Aborigines)

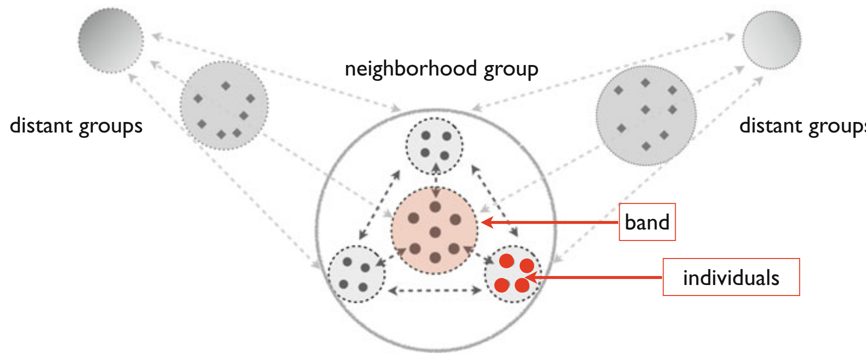


Fig. 8.2 Image of bands and their social networks

resources is not limited to the band members. Various people, such as maternal kin and spouses' relatives, can use it as long as they get permission to do so (Kelly 1995).

3. The band's members share social values such as cooperation, reciprocity, sharing, and egalitarianism. Egalitarianism appears in various parts of everyday life such as food sharing and human relationships. There is no chief or special person who controls the group. The hunter-gatherers generally dislike to give or be given orders.
4. There are wide social networks which promote the exchange of people, goods and ideas. People move frequently from band to band according to various reasons. There is no doubt that modern hunter-gatherers' various learning behaviors have developed based on these social and ecological fundamentals.

8.2.2 Bands and Social Networks

As mentioned above, each hunter-gatherer band has political autonomy and can make decisions independently from other bands or other people. Just as there is no leader for individual bands, there is no paramount chief who governs the whole society. However, bands are not isolated from each other. They are linked by kinship and friendship ties that extend widely over the land (Fig. 8.2). The links are not created only between groups, but rather between individuals. The networks extend through various individual links to the end of the society.

Some hunter-gatherer bands which are in a friendly relationship often make their camps near one another, which I call a neighborhood group. Within the neighborhood group, there are frequent mutual visits. In addition, there are distant groups that are located beyond the range of a one-day trip. One finds the occasional movement of people even between groups located a distance of more than a few traveling days away from each other.

Steven Kuhn (see Chap. 6) notes that Middle Paleolithic hunter-gatherers were demographically characterized by small group living and were sparsely distributed on their land, which might have been the cause of the scarcity of innovations in their culture. That same demographic makeup is common in most modern hunter-gatherer bands. The population density of modern nomadic hunter-gatherers is usually much less than 1 person per 1 km^2, and in some cases even less that 1 person per 100 km^2 (Kelly 1995). However, the formation of social networks between bands of modern hunter-gatherers shown in the Fig. 8.2 seems to help to achieve both the sociological benefit of integrating people and ecologically effective resource use, the latter of which is accomplished by moving in small groups while keeping the autonomy of each band intact. This particular social formation aids internal communication and cooperation among bands which bring about the transportation of new information, ideas and innovations.

8.3 Patterns of Development and Learning in Modern Hunter-Gatherers

Childhood is defined as a unique developmental stage of humans (Bogin 1997). It is noteworthy that modern hunter-gatherers have a long period before arriving at adulthood, which stretches from infancy to adolescence and semi-adulthood. This stands in contrast to the Neanderthals who might have had a limited childhood (Thompson and Nelson 2011; Smith et al. 2010). This long childhood means that the modern hunter-gatherer children have quite a long learning period that contributes to producing our unique human culture. Childhood is also said to be a crucial time for brain development and is certainly an important period for learning (Bogin 1997). During childhood, hunter-gatherer children often help adults with their housework. They sometimes accompany adults during subsistence work, but they are not forced to do so. It depends on the individual child's preference and they can freely engage in play activities. This contrasts to the children of agricultural and pastoral societies where they are expected to do various routine jobs in farming or stock keeping.

The figure (Fig. 8.3) shows the development pattern in hunting and gathering societies. Although five stages of human life

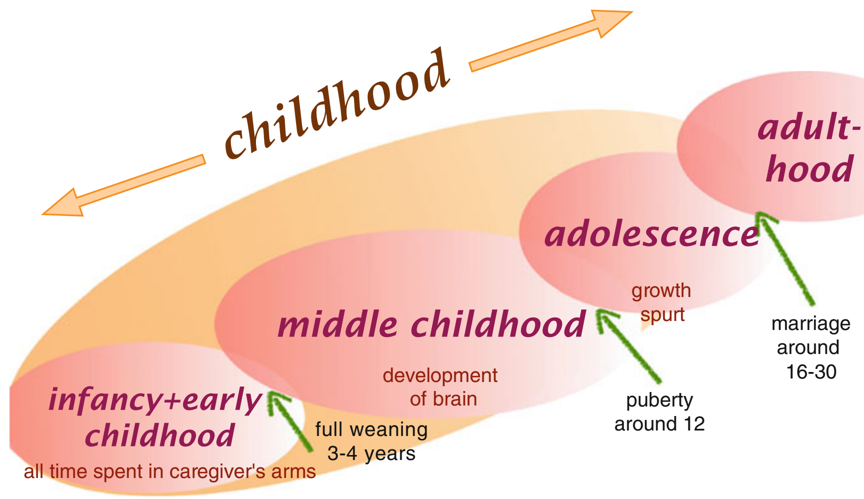


Fig. 8.3 Child development pattern in hunting and gathering societies

history are posited by scholars (Bogin 2006; Thompson and Nelson 2011) (infancy, early childhood, middle childhood, adolescence, and adulthood) here I use four categories, combining infancy and early childhood. Here I have summarized the development of learning in hunter-gatherers along with the steps of physical development.

8.3.1 Infancy and Early Childhood

The first category of hunter-gatherer childhood development is "infancy and early childhood." From the time of birth to the weaning, infants are mostly in the arms of caregivers such as mothers and fathers, grandparents, and older siblings. They do nothing but receive continuous care and interaction from them. Hunter-gatherer children in this period are mostly accepted and indulged with a lot of affection by various members of the same group (Hewlett 1992; Lawlor 1991; Briggs 1972).

From the onset of infancy certain innate social learning processes begin that can be called a kind of education. Infants respond almost automatically to the "teaching" signals of adults. Cognitive psychologists Gergely Csibra and György Gergely call this kind of interaction "natural pedagogy" and claim that this is a special kind of communication most basic in human evolution and that it may have started even before the development of language (Csibra and Gergely 2006). I will show more details on natural pedagogy later.

Childhood is defined as the period following infancy (Bogin 1997), when the youngster is weaned from nursing but still depends on older people for feeding and protection. Hunter-gatherers wean their children around 3 or 4 years of age, much later than people of other subsistence modes. It takes long time to wean the child in hunter-gatherers since the decision of keeping away the mother's breasts is usually up to the child.

8.3.2 Middle Childhood

The period of infancy ends with weaning. Middle childhood lasts until the onset of puberty, which starts around 12–13 years of age. The brain develops to almost adult size during the early stage of this middle childhood period, at the age of 6 or 7.

After weaning, children's learning behavior changes drastically. They join in play groups consisting of children of a variety of ages and gain a wealth of knowledge through play activities. In particular, boys and girls often pretend to do subsistence activities such as hunting, fishing and gathering. These play actitivities are very important for children not only to obtain knowledge and skills for those subsistence activities but also to learn about nature.

During middle childhood, children carry out social and individual learning. Autonomous learning through observation and imitation is the most common learning method. In this stage, there is no formal teaching, at least not in the form of the structured western pedagogical model that most of us are familiar with. The problem of teaching or, more precisely, the problem of "non-teaching," is discussed in the next section.

In most social animal species, the childhood stage changes into juvenile stage after the children begin to be independent on older individuals for feeding and protection prior to the onset of reproductive maturation (Bogin 1997). In human societies with other subsistence types than hunting and gathering, juveniles are expected to do a lot of routine jobs with adults. In hunter-gatherer societies, however, children in that stage are not counted as part of the labor force. Hence, the juvenile stage can be seen as an extention of childhood in terms of their social role.

8.3.3 Puberty and Adolescence

Adolescence begins with physical growth spurt at the onset of puberty. Puberty and adolescence are a critical stage of human development. Taro Yamauchi and Izumi Hagino's study of the Baka pygmy children shows that the daily activities of young people, particularly young men, increase sharply along with this growth spurt (Yamauchi and Hagino 2013).

Adolescents enjoy various activities, with opportunities for both socialization and learning. The following are some examples of each:

1. Boys usually do not have routine work to do. They enjoy playing with younger children, going for a walk in the forest, or voluntarily participating in subsistence work in an adult group.
2. Starting in adolescence, young males begin to attempt difficult hunts, after large game for example. At times they apprentice themselves to adult hunters.
3. Girls, on the other hand, begin to learn innovative basket and ground mat weaving. Sometimes they ask their elders to demonstrate difficult work.
4. They explore the natural environment during daily activities and expand their scientific knowledge about nature, finally gaining an understanding of the mechanisms of nature. It is something like the study of ecology and natural history on their own.
5. Boys as well as girls often visit other bands or villages of neighbors without a specific purpose. Boys visit distant groups more than a day's walk away sometimes, one of their goals being to find a future mate. Such a visit intensifies the social network between the bands and may bring about occasions for the transmission of information and culture.
6. Adolescent girls and boys sing and dance in ritual performances or for enjoyment, playing a very important part in ceremonies and everyday entertainment.
7. In most societies, boys and girls have to experience an initiation ceremony where they are isolated from normal life and taught various things including esoteric knowledge about their life in relation to the ancestral world.

Adolescence is the period of expansion of social learning and the undertaking of new and difficult challenges, spurred on by rapid bodily growth and expanding social networks. Teaching plays a huge role in giving the young the knowledge necessary for successful adult life.

8.3.4 Adulthood

Marriage in hunter-gatherer bands takes place around 16-18 years of age for girls and around 20-30 years of age for boys (Kelly 1995). The timing of marriage is determined chiefly by physical maturity in girls, but in boys other factors such as social attributes are taken into account. After marriage young people enter into full adulthood. The expansion of social activities in adolescence promotes the frequent exchange of goods and ideas between groups and leads to innovative learning and activities in adulthood based on wide-range communication.

8.4 Teaching Problems in Hunting and Gathering Society

As suggested above, in hunting and gathering societies the most apparent feature of their learning behavior is the autonomy of the learners. Adults usually avoid giving direct instructions to children except for on some special occasions. Direct teaching is rare and children learn by observing and imitating others through everyday activities and particularly through collective play with other children. The most powerful method of learning is through observation, and this method is found not only in humans but also in many other animals. The children's participation in communal activities is almost sufficient to teach them the knowledge and skills that they need for everyday activities (Paradise and Rogoff 2009). This style of autonomous learning without being taught by force seems to foster creativity and adaptability in children, elements which are very important in hunting and gathering activities.

Verbal instructions, however, are necessary for teaching invisible things such as social norms and values. In childhood, kinship relationships are taught alongside respectful kin terms, proper behavior and polite speech to adults. Social manners and morals such as sharing, cooperation and friendly behavior should be taught, too (Guemple 1988; Lawlor 1991). Although hunter-gatherers do not verbally teach subsistence skills to children, they usually desire to teach at least those skills necessary for social integration. Language is not employed in straightforwardly, but rather indirectly when teaching these invisible norms and values: for example, storytelling that contains many symbolic and metaphorical representations.

Hunter-gatherers usually enjoy talking after the evening meal and in their spare time. They like to tell the children stories consisting of various anthropomorphic images. Anthropomorphism is sometimes considered to be a primitive way of thinking, but its symbolic imagery works well to convey sophisticated social meanings (Lévi-Strauss 1962; Yano 2002). Anthropomorphism is related to the development of various cognitive abilities such as multi-representation and is used as a unique and excellent method of our species for representing real-world situations, particularly when they have to face difficult dilemmas.

Ritual ceremonies such as initiation rites also serve as an occasion to teach social values and morals that are rather difficult to teach with only verbal instruction. During the performances children come to recognize that there is an invisible world and secrets that are not seen in mundane life. They gradually learn their connection with and the identities of the ancestors as they take in traditional knowledge. Some rituals are held by several bands collectively, and many hunter-gatherers from distant groups come. During such occasions, the exchange of information and numerous new cultural items takes place, which leads to the transmission and development of innovations (see Chap. 14).

It is a fairly common opinion among cultural anthropologists that not only the hunter-gatherers but also agriculturalists, pastoralists and other people they lived with rarely taught their children or showed educational behavior (Lancy 2010; Lancy et al. 2010). Hunter-gatherers usually wait until children learn and understand on their own except for brief lessons in social conduct. They believe that before arriving at the proper age of 5 or 6, children are simply not "educable." On the other hand, philosophers claim that humans are the only animals that has to be educated (Rousseau 1966; Kant 2007). And it is a common idea in industrialized society that education assists the cognitive as well as physical development of children. If so, this begs the question of why, in actuality, do humans rarely teach their children except in some developed countries? The relationship between learning and teaching is not so simple and we must explore the methods of and the idea of the value of teaching or education in a wider context to gain deeper insight.

8.5 The Evolution of Education

Here I will propose a rough sketch of the evolutionary stages of the human educational system (Fig. 8.4). By the word "education," or "educational system" I mean the whole system of transmission of knowledge and skills not only by teaching that is defined as a transmission of knowledge and skills based on interaction between the "learner" and the "teacher" but also by any kind of social learning behavior.

8.5.1 Social Learning Based on Biological Adaptation

First, on the most basic level of education, there is the biologically established ability of social learning. Many animals, including higher non-human primates such as chimpanzees and bonobos, chiefly stay on this stage. Humans also inherit the most basic ability of this learning stage. Social learning does not presuppose the existence of a counterpart, the teacher, but in the case of humans the learners always need other persons or natural things to be their model to learn effectively.

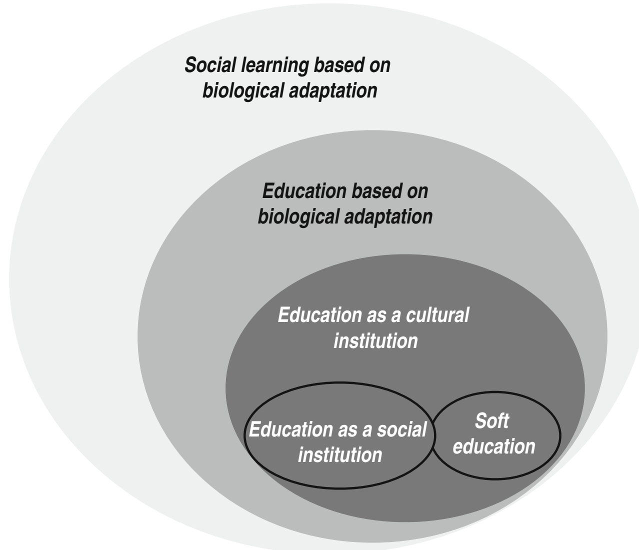


Fig. 8.4 An outline of evolution of education in humans

8.5.2 Education Based on Biological Adaptation

In the second stage education appears as a biological adaptation. This makes up the most basic layer of the human teaching-learning system. Csibra and Gergely (2006, 2009) claim that human beings are equipped with "natural pedagogy" which is a style of communication consisting of three elements—"ostension," "reference" and "relevance"—to transfer knowledge and skills efficiently. They explain that human infants are prepared to receive information from adults as natural pedagogy (1) by being sensitive to ostensive signals that indicate they are being addressed, (2) by developing referential expectations in that context, and (3) by being biased to interpret ostensive-referential communication as conveying information that is kind-relevant and generalizable.

Sidney Strauss (2005) and Strauss and his colleagues (2002) suggest that teaching is a special kind of social interaction that has intention to enhance the learner's knowledge and understanding. They find that teaching behavior begins in children at around 3-4 years of age, and claim that teaching may be a natural cognitive skill which is universal and learned without any apparent outside influence.

The idea that humans have innate teaching and learning behavior assumes great importance when considering the evolution of human learning. This suggests that there is a definite biological foundation for education, such that could create the large gap between humans and other animals.

The investigations on innate educational abilities, however, are just beginning to be studied in a natural setting (Hewlett 2013). They have been carried out so far only in psychological laboratories and facilities in industrial, and therefore artificial, settings. It is necessary to expand the range of investigation to other societies, especially hunting and gathering societies by observing their daily activities in natural settings.

8.5.3 Education As a Cultural Institution

In the third stage a new type of educational style was created based on the development of cognitive abilities such as language and particularly the "theory of mind" (Strauss 2005; Strauss et al. 2002; Leslie 1987, 2004). Let us call this type of education a cultural institution. The word "institution" means here a culturally established relationship and interaction between the person who learns and the person who teaches.

The point of this educational system is that the educational relationships is usually recognized by both the learner and the teacher. The learner expects that the person regarded as the teacher will gives something that the learner need to obtain, and conversely, the teacher expects that the person regarded as the learner will accept what the teacher is going to teach. Both the learner and the teacher are given the status assigned to them in a cultural and educational context, so being "institutional" according to John Searle's definition (Searle 2005). This relationship is in contrast to the biologically established relationship in the case of natural pedagogy described above. Education as a cultural institution is a socio-cultural interaction within a framework of intention and expectation, belief and trust between the learner and the teacher, centering around a new experience for the learner.

The recognition of the status of one's partner in this context often corresponds to one another's belief; that is, when one considers the other as a teacher, the latter regards the former as a learner. However, this mutual recognition is not necessary all the time. People often behave as teachers unconsciously, and conversely, people can be taught by something other than another human. It is a prevailing idea among people who have intimate interaction with nature that natural things such as animals and even plants can teach them such as in this excerpt from a story told by a famous Ainu hunter in Hokkaido, Japan:

"I really think that the bear is my teacher. When I was young I didn't know anything about hunting. Then I decided to follow after the bear in the mountain, walking through the mountain as the bear did, taking a rest as the bear did, tried to feel and think as the bear did. I imitated everything that the bear did. Through those experiences, I obtained all the knowledge on nature and hunting. So, I could say that I learned everything from the bear, at last to have found myself scarcely different from the bear" (Anezaki and Katayama 2002).

The belief that one can learn even from a bear demonstrates the importance of attitude when one is learning. When the learner has a positive attitude towards learning, the learner recognizes anything he/she interacts can be a source of learning experience. This indicates that in this type of human education, the initiative of learning is in the hands of the learner, while the teacher gives only suggestions and indirect support expecting that the learner will learn what is necessary by themselves. Teaching in an educational environment where the learner can feel secure to learn with trust in the teacher brings a high level of development in the learner, but when teaching is heavy-handed, it may not foster the learner's development at all (Watabe 2010a, b). This type of education as a cultural institution is what anthropologists found in most hunting and gathering societies.

8.5.4 Education As a Social Institution

The fourth stage of educational development is education as a social institution. This type of education started with the advent of modernization in the nineteenth century mainly in order to produce human resources for the establishment of modern states based on industrial production, a model that has now prevailed all over the world. This is what we usually imagine when we think of an "educational institution" and the concept is mainly connected with schools. Education in a school used to postulate that the students are tabula rasa, a blank slate with nothing written on it, and that teaching is necessary to give children the knowledge and skills that would not otherwise be available to them. In this model of education, the children are supposed to be passive and incapable agents. Thus, it should be effective to cram knowledge into them under the teacher's control to produce standardized human resources. Although this education system has prevailed in the modern world, it is doubtful whether it is the best way for children to develop their full potential. It may only serve to meet the needs of an industrialized society.

8.5.5 A Soft Education

There seems to be one more type of education which is developing from education as a social institution; that is, "soft education" as posited by Watabe (2010a, b). We now realize that the conventional institutionalized education, which could be called "hard education," faces difficulties in many societies. It is said that hard education has become maladaptive to a swiftly-changing society that is based on innovative knowledge and information.

Soft education takes advantage of the learner's initiative, in contrast to that of the teacher's in hard education. It also uses the affordance of the surrounding environment to provide necessary knowledge for the learner, much like the process of osmosis. When one learns one's native tongue, it is through immersion, and not by teaching. In this model, children are supposed to learn on their own if they are surrounded by a good environment and good models. It helps to develop the thinking ability of the learner and lead to innovative learning and thinking in the future. However, because soft education is just emerging in our contemporary society, many points about it should be carefully considered. We still do not have clear ideas about concrete methods and objectives in soft education, although more stress is being put on finding them.

Soft education and education as a social institution as shown above are a kind of adaptation of education to a specific social organization and needs, and may not be considered as the evolution of education.

8.6 Learning Performance and Hunting and Gathering Life

The three pictures in Fig. 8.5 show external similarities in learning behavior in modern humans, Neanderthals, and chimpanzees: (a) the photo shows a human mother preparing fish and her daughter looking at her mother's work, (b) the image shows a Neanderthal mother making a stone tool with her child aside while he's attention is distracted from her work, and (c) the photo shows a female chimpanzee foraging ants from the hole on a tree trunk and her younger sister observes her actions. All of these scenes show a mother doing something and a child observing what its mother does. These may be called the scenes of education. But behind the surface similarities, there may exist significant differences that have allowed only *Homo sapiens* their remarkable evolution in the form of cumulative culture. In our ongoing research project RNMH, "the Replacement of Neanderthals by Modern Humans," we postulate that it is the differences in each group's respective learning abilities that have produced innovation in various fields only in modern humans.

We have observed that many resources in the life of modern hunter-gatherers seem to support their learning and innovative activities both directly and indirectly. It is also apparent that the evolution of learning performance depends not only on a few prominent resources but on the synthetic development of every resource. I have constructed a tentative map of these resources, which are largely classified into three domains: (1) The biological and ecological system or bio-ecological system, (2) the social system, and (3) the cognitive system.

Cognitive science has revealed the importance of the development of meta-cognition and meta-learning in modern humans on the basis of enhanced cognitive ability and brain function. Our fieldwork also suggests the usefulness of meta-cognition and meta-learning in hunter-gatherers' daily lives. The theory of mind, i.e. the ability to think about another person's behavior by putting oneself in their shoes, works in learning through imitation as well as in education as a cultural institution. The large morphological differences between the Neanderthal brain and that of modern humans

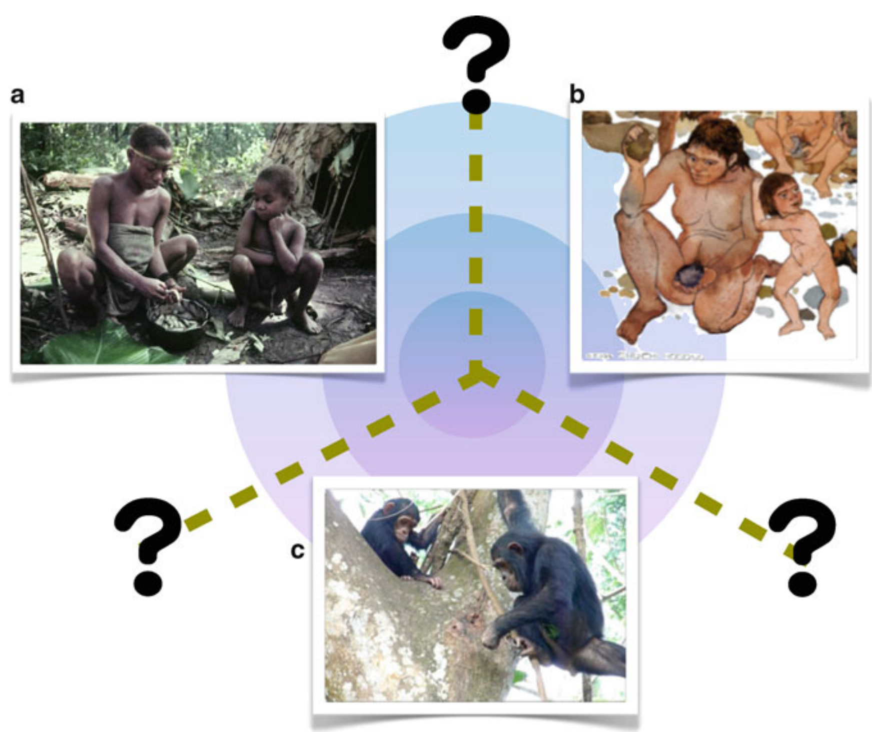


Fig. 8.5 What is the difference between them? Pictures are courtesy of is Mine (**a**) Shuichi (**b**) Hosono and (**c**) Michio Nakamura

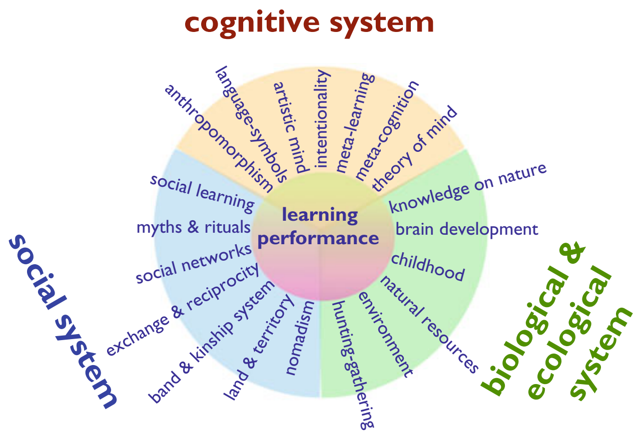


Fig. 8.6 Learning performance in modern hunter-gatherers

suggests some important functional differences between them, one of which may be the difference of learning ability on the level of meta-cognition. It is assumed that language, symbolic signs and artistic representations all of which are related to the enhanced cognitive abilities play a large part in learning and teaching invisible things like social values, customs, and the life and history of their ancestors.

Psychological investigations have shown various characteristics of cognitive abilities in the Baka children of southeast Cameroon. Two researchers did psychological studies there. Eiko Yamagami investigated the children's collage expressions, free picture drawings and the "Hand-Test," a simple projective technique widely used to measure action tendencies in adults and children, introduced by Wagner (1983). Her study suggests Baka children's curiosity, creativity, and resilience. All of these are very important cognitive abilities when one faces new experiences (Yamagami 2013). Tadashi Koyama conducted a comprehension test of visual signs and pictures that also showed their intuition and receptivity to such signs and visual reception. The way that the children managed to create objects from their imagination and own ideas also suggested their cognitive flexibility (Koyama 2013).

Cultural innovation in hunting and gathering societies covers very wide domains from material culture—such as foraging tools, clothing and housing—to non-material items such as rituals, songs, dances, plays, and bodily decorations. Most of those innovations are not made individually in each group but are transmitted from place to place once they are made in a single group. Modern hunter-gatherers have widespread networks and frequently pay visits to relatives and friends in distant places. This interconnectivity between people brings about opportunities for the exchange of goods and ideas as well as the people themselves (see Fig. 8.2). Innovation becomes introduced, recognized and fixed through its movement to other areas where it may give birth to a new innovation or improvement in turn. Comparison between Neanderthals and modern humans in terms of range of mobility and social networking may help to understand the comparative degree of Neanderthals' cultural innovation.

Humans' bio-ecological system supports their social and cognitive system. In particular, the long childhood of *Homo sapiens* should have contributed greatly to modern humans' learning performance. More data is expected to be discovered about childhood development, ecological adaptation and the social system of Neanderthals, which may give us the opportunity to make a more comprehensive comparison with our data on modern hunter-gatherers and give us greater insight into their learning ability.

As for modern hunter-gatherer children, many now receive an elementary education provided by the government, religious missionaries, or NPOs. However, the "education as a cultural institution" described above seems to make the most important contribution to helping them learn and inherit their culture and create innovations as they adapt to the ever-changing conditions of subsistence and social life.

Neanderthals seem to have transmitted their cultural heritage via excellent social teaching and learning. They were thought to have passed down the knowledge to copy stone tools that maintained almost the same shape for hundreds of generations. However, the development of innovative behavior and social networks might have been insufficient. The ability to handle meta-cognition which needs to be supported by language and manipulation of symbolic signs did not seem to have developed at that time.

In *Homo sapiens*, however, a big change took place in learning capacity due to the development of cognitive ability, in particular meta-cognition and meta-learning; that is, the ability to learn about learning. Development of cognitive ability may have enhanced their knowledge on nature enormously and brought about the development of imaginative and symbolic thought. The latter may have accelerated more learning from nature itself and should have contributed much to hunting and gathering. Blurton-Jones and Konner (1976) were quite surprised that the !Kung Bushmen's rich knowledge about the natural world was often more accurate and correct than that of western scientists. Furthermore, the !Kung have an enormous passion for learning the particulars of each animal species in their environment. They even admit that "we have gained little or nothing in ability or intellectural brilliance since the Stone Age; our gains have all been in the accumulation of records of our intellectual achievements. We climb on each other's back; we know more and understand more, but our intellects are no better." (Blurton-Jones and Konner 1976, p. 348). Thus, it is clear that the hunting and gathering way of life necessitates flexible and creative individual learning in *Homo sapiens* along with rapid and accurate social learning which together produce a powerful learning strategy in modern humans.

References

Anezaki H, Katayama T (2002) What do you have to do when you come across with the bear (in Japanese). Kirakusha, Tokyo

Blurton-Jones N, Konner MJ (1976) !Kung knowledge of animal behavior (or: the proper study of mankind is animals). In: Lee R, DeVore I (eds) Kalahari hunter-gatherers: study of the !Kung San and their neighbors. Harvard University Press, Cambridge, pp 324–358

Bogin B (1997) Evolutionary hypotheses for human childhood. Yearbook Physic Anthropol 40:63–89

Bogin B (2006) Modern human life history: the evolution of human childhood and fertility. In: Kawkes K, Paine RR (eds) The evolution of human life history. School of American Research Press, Santa Fe, New Mexico, pp 197–230

Briggs LJ (1972) Never in anger: portrait of an Eskimo family. Harvard University Press, Cambridge

Chen Y-S, Olckers A, Schurr TG, Kogelnik AM, Huoponen K, Wallace DC (2000) mtDNA variation in the south African Kung and Khwe—and their genetic relationships to other African populations. Am J Hum Genet 66(4):1362–1383

Csibra G, Gergely G (2006) Social learning and social cognition: the case for pedagogy. In: Munakata Y, Johnson MH (eds) Processes of change in brain and cognitive development: attention and performance XXI. Oxford University Press, Oxford, pp 249–274

Csibra G, Gergely G (2009) Natural pedagogy. Trends Cogn Sci 13:148–153

Guemple L (1988) Teaching social relations to Inuit children. In: Ingold T, Riches D, Woodburn J (eds) Hunters and gatherers 2: property, power and ideology. Berg Publishers Ltd, Oxford, pp 131–149

Hewlett BS (1992) Intimate fathers: the nature and context of aka pygmy paternal infant care. The University of Michigan Press, Ann Arbor

Hewlett BL (2013) Ekeloko: The spirit to create: Innovation and social learning among Aka Adolescents of the Central African rainforest. In: Akazawa T, Aoki K and Nishiaki Y (eds) Dynamics of learning in Neanderthals and modern humans: Cultural perspectives, vol 1. Springer, New York

Hovers E, Malinsky-Buller A, Goder-Goldberger M, Ekshtain R (2011) Capturing a moment: identifying short-lived activity locations in Amud Cave, Israel. In: Le Tensorer J-M, Jagher R, Otte M (eds) The Lower and Middle Palaeolithic in the Middle East and neighbouring regions, vol 126. ERAUL, Liège, pp 101–114

Kant I (2007) Anthropology, history, and education (The Cambridge edition of the works of Immanuel Kant). Cambridge University Press, Cambridge

Kelly RL (1995) The Foraging spectrum. Smithsonian Institution Press, Washington

Koyama T (2013) Cognitive flexibility and making objects in Baka pygmy children. In: Akazawa T, Ogihara N, Tanabe HC, Terashima H (eds) Dynamics of learning in Neanderthals and modern humans: cognitive and physical perspectives, vol 2. Springer, New York

Lancy DF (2010) Learning 'from nobody': the limited role of teaching in folk models of children's development. Childhood Past 3:79–106

Lancy DF, Bock J, Gaskins S (eds) (2010) The anthropology of learning in childhood. AltaMira, Plymouth

Lawlor R (1991) Voices of the first day. Inner Traditions International Limited, Rochester

Leslie AM (1987) Pretense and representation: the origins of "theory of mind". Psychol Rev 94(4):412–426

Leslie AM (2004) Core mechanisms in 'theory of mind'. Trends Cogn Sci 8(12):528–533

Lévi-Strauss C (1962) La pensée sauvage. Librairie Plon, Paris

Maruyama J (2010) Henka o ikinuku Bushmen (Bushmen who thrive on changes and challenges). Sekai Shiso-sha, Kyoto

Paradise R, Rogoff B (2009) Side by side: Learning by observing and pitching in. Ethos 37(1):102–138

Pigeot N (1990) Technical and social actors: flintknapping specialists and apprentices at Magdalenian Etiolles. Archaeol Rev Cam 9(1):126–141

Radcliff-Brown AR (1930/31) The social organization of Australian tribes. Oceania 1:34–63

Rousseau J-J (1966) Émile ou de L'Éducation. Garnier-Flammarion, Paris

Searle J (2005) What is an institution. J Institutional Economics 1(1):1–22

Smith TM et al (2010) Dental evidence for ontogenetic differences between modern humans and Neanderthals. Proc Natl Acad Sci U S A 107(49):20923–20928

Strauss S (2005) Teaching as a natural cognitive ability: implications for classroom practice and teacher education. In: Pillemer D, White S (eds) Developmental psychology and social change. Cambridge University Press, New York, pp 368–388

Strauss S, Ziv M, Stein A (2002) Teaching as a natural cognition and its relations to preschoolers' developing theory of mind. Cogn Dev 17:1473–1487

Thompson JL, Nelson AJ (2011) Middle childhood and modern human origins. Hum Nat 22:249–280

Wagner EE (1983) The hand test manual. Western Psychological Service, Torrance

Watabe S (2010a) Rethinking 'education' in a society based on knowledge and information: an approach from the theory of 'learning' in cognitive science (in Japanese). Kyoikugaku Kenkyu 77(4):14–25

Watabe S (ed) (2010b) A companion to the cognitive science of learning (in Japanese). Taishukan, Tokyo

Wilmsen EN (1989) Land filled with flies: a political economy of the Kalahari. The University of Chicago Press, Chicago

Woodburn J (1988) African hunter-gatherers social organization: Is it best understood as a product of encapsulation? In: Ingold T, Riches D, Woodburn J (eds) Hunters and gatherers 1: history, evolution and social change. Berg Publishers Ltd, Oxford, pp 31–64

Yamagami E (2013) The demonstration of resilience in the drawings of Baka Pygmy children. In: Akazawa T, Ogihara N, Tanabe HC, Terashima H (eds) Dynamics of learning in Neanderthals and modern humans: cognitive and physical perspectives, vol 2. Springer, New York

Yamauchi T, Hagino I (2013) Estimation of the period of childhood and child growth characteristics of pygmy hunter-gatherers in southeast Cameroon. In: Akazawa T, Ogihara N, Tanabe HC, Terashima H (eds) Dynamics of learning in Neanderthals and modern humans: cognitive and physical perspectives, vol 2. Springer, New York

Yano S (2002) Adventure on animal story books for children: a lesson in zoology and anthropology (in Japanse). Keiso Shobo, Tokyo

9 Using Lithic Refitting to Investigate the Skill Learning Process: Lessons from Upper Paleolithic Assemblages at the Shirataki Sites in Hokkaido, Northern Japan

Jun Takakura

Abstract

This paper investigates skill acquisition in the past through the analysis of refitted sets of lithic artifacts. The refitted sets belong to the late Upper Paleolithic (cal. 17–14 ka), and were obtained from the Hattoridai 2, Kamishirataki 2, and Kamishirataki 8 sites in Hokkaido, Northern Japan. Notable findings include the following. (1) Highly skilled knappers used various raw materials for blade production at the Kamishirataki 8 site. This suggests that the particular choice of lithic raw material “packages” is not always associated with different skill levels among knappers at the stage of lithic manufacture. (2) Missing blade cores (“ghost cores”) as well as missing blades (“ghost blades”) among the refitted sets can offer a useful signature of the knappers’ skill. (3) Novice knappers carried out simple training exercises at the Hattoridai 2 site, whereas the refitted sets from the Kamishirataki 2 site suggest that experts conducted pedagogical demonstrations for the benefit of one or more novices. The main conclusion from the analyses presented in this paper is that observation and imitation, as well as some kind of instruction, played significant roles in the skill learning process among the inhabitants of these Upper Paleolithic sites.

Keywords

Blade reduction • Lithic refitting • Shirataki sites • Skill learning • Upper Paleolithic

9.1 Introduction

Previous studies of prehistoric lithic assemblages, based on either culture-historical or human-ecological perspectives, have made an implicit assumption that knappers in the past shared an identical technological tradition and competence within their own specific community. Most of these approaches employed to understand prehistoric lithic technology have been characterized by a macro-scale orientation which tends to focus on an evaluation of inter-assemblage variability (Dobres and Hoffman 1994). This has provided archaeologists with a powerful means of addressing questions associated with the reconstruction of cultural traditions and the study of resource management and land use among prehistoric hunter-gatherers. However, such approaches usually lack explicit and sustained interest in micro-scale social contexts, such as the active role of past agents in creating and manipulating the material culture (Dobres 1995).

Archaeologists still understand little about how knappers in the past actually acquired and transmitted the knowledge and know-how necessary for lithic production, although such cultural information was universally transmitted between generations. An understanding of the learning and skill transmission process should have important implications for the study of prehistoric societies, because it offers us the potential to document the child as well as the development of the craft specialists in a given society (Finlay 1997; Grimm 2000; Minar and Crown 2001). Previous studies have led to an over-simplification in the evaluation of technological

J. Takakura (✉)
Archaeological Research Center on the Campus, Hokkaido University, Kita-ku, Sapporo, Hokkaido 060-0811, Japan
e-mail: jun-ta@let.hokudai.ac.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_9,

variation at the intra-assemblage level. However, recently some methodological and theoretical discussions regarding how skill can be defined and how skill can be acquired—discussions based on diverse implications obtained from experimental and ethnoarchaeological research—have played a fundamental role in clarifying the learning and skill transmission processes in the archaeological record (e.g., Bleed 2008; Clark 2003; Eren et al. 2011; Geribàs et al. 2010; Pelegrin 1990; Shelley 1990; Stout 2002). Such research shows that archaeologists need to focus on technological variation within certain lithic assemblages in order to evaluate uneven expressions of skill within a given community.

The refitting of lithic tools and production debitage can be viewed as reflecting knapping activities carried out at a specific time in the past at the place of discovery. An analysis of the spatial patterning of the refitted sets may reveal past human behavior involved in the skill transmission process. The study of lithic refitting, paying special attention to differences in knappers' competence at lithic manufacture, may offer rich information about the skills expressed materially by past knappers, along with the operational sequences in lithic production. Where numerous pieces of artifacts, such as cores, blades or microblades, retouched tools, and debitage, have been successfully conjoined, we can directly understand how past stoneworkers operated and organized their activities, as well as which technological choices and decisions they made or did not make, from the initial acquisition of raw materials through to tool manufacture, use, and discard (Bleed 2002; Takakura 2010).

The main purpose of this paper is to explore various applications of lithic refitting in an investigation of the learning and skill transmission process in lithic production. In particular, this paper presents an attempt to assess the methodological issues regarding the evaluation of the lithic refitted pieces to prove the skill transmission process in prehistoric contexts. I approach this through a brief review of recent discussions concerning such issue and an analysis of the large quantity of lithic refitted pieces from Upper Paleolithic assemblages at the Shirataki sites in Hokkaido, Northern Japan. Because of the wealth of information that can been obtained from lithic refitting, careful analysis of these materials can deepen our understanding not only of the chrono-cultural sequence of the Upper Paleolithic period in Hokkaido from a techno-typological perspective, but also of the technological characteristics of the lithic reduction sequences in various lithic assemblages. These materials also potentially provide us with a reconstruction of knapping activities and their behavioral contexts in terms of the chaîne opératoire approach (e.g., Audouze and Valentin 2010; Pelegrin et al. 1988; Pigeot 1990; Soressi and Geneste 2011). Analyzing and comparing these lithic refitted pieces may perhaps encourage us to examine the relationship between the contexts of past knapping activities that occurred at the site and how skill was acquired and materially expressed.

The rest of this paper is organized as follows. I will first offer some of the background information necessary to consider the learning and skill transmission process in lithic production. This is followed by a brief description of the Shirataki sites. Refitted sets from the Shirataki sites are then discussed and compared, with special reference to blade reduction sequences. The implications of these commonalities and differences are discussed with particular regard to insights they may offer into technological variation at the intra-assemblage level, which is understood to reflect different technical skill levels.

9.2 Placing Skill in a Behavioral Context

There is a fairly broad consensus that sophisticated lithic manufacturing requires a great deal of practice and knowledge before good results can be achieved consistently (e.g., Clark 2003; Pelegrin 1990). The skills relevant to lithic production must be behaviorally acquired and developed, rather than simply learned like a series of facts. Repeated practice is essential to any systematic success in the operations involved. The durable nature of stone and the sequential character of chipped stone technology ensure that information relevant to novice knapping episodes can be preserved in lithic artefactual materials recovered from archaeological sites, thus making the skill learning process accessible to archaeological observation (e.g., Bamforth and Finlay 2008; Bleed 2008; Grimm 2000; Roux et al. 1995). The evidence gained from lithic refitting can be even more suitable for addressing such an issue. In addition, the spatial patterning of lithic refitted artifacts allows us to consider the skill learning processes that occurred at prehistoric sites. In an attempt to examine this process by analyzing the lithic refitted artifacts and their spatial patterning at a site, it is necessary to identify the outcome of activities by knappers possessing different skill levels from the analysis of lithic refitted artifacts.

Indeed, investigations carried out at some of the Magdalenian open-air sites in the Paris Basin, France, such as Étiolles, Pincevent, Marsangy, and Verberie, have produced important case studies that use refitting in attempts to identify the technical skill levels associated with flint blades and bladelet production (see Bodu et al. 1990; Janny 2010; Karlin et al. 1993; Olive 1988; Pigeot 1987, 1990, 2004, 2010 and many others). These studies have also aimed at understanding the composition of domestic units and the socio-economic organization involved in technical activities.

In Japan, pioneering work addressing the identification of technical skill levels based on the technological analysis of blade cores and microblade cores has been carried out for at least a decade (Abe 2003, 2004, 2009). In particular, at Suichouen, an Upper Paleolithic site in Western Japan, the recovery of numerous refitted sets relevant to the reduction processes of the Setouchi method have offered interesting suggestions about the composition of domestic units and the skill learning processes that occurred within them (Takahashi 2001). With the recovery of microblade assemblages related to the Yubetsu method at the Onbara 1 site in Western Japan, a difference of skills among the knappers has been discussed, based on some of refitted sets (Mitsuishi 2009). Part of the refitted sets obtained from the Shirataki sites, which I will analyze in this paper, has been assessed to prove a difference of skill among the knappers (Naoe 2003, 2007). These studies have particularly focused on some of the technological features such as the careful preparation and maintenance of the core volume as well as the appropriate restoration of errors in order to evaluate the technical skill levels among the knappers. It is apparent that an analysis of the technological features and spatial patterning of the refitted sets found at these sites has provided considerable insight into the micro-scale social context of lithic production.

Recently, there has been much discussion of the criteria upon which the determination of technical skill levels through the refitting of artifacts should be based (e.g., Bamforth and Finlay 2008; Finlay 2008; Perdaen and Noens 2011). A fundamental obstacle is that the relationship between an archaeological artifact and skill is complex and may be difficult to deal with. In an attempt to identify technical skill levels, recent approaches have often relied upon a number of qualitative value judgments such as productivity, precision, regularity, the patterned multistage of operations, and so on. These judgments draw our attention to both the result of an action and the way it is performed.

Yet what levels of consistency in production we should expect remains obscure. As demonstrated by some researchers (Audouze and Cattin 2011; Ferguson 2008; Finlay 2011; Shea 2006; Sternke 2011; Stout 2002), skill and its material expression depend to a certain degree on the lithic raw materials used and their availability. Needless to say, the contexts of knapping activities, technological needs, and the availability of raw materials might significantly affect the operational sequences employed by knappers (Takakura 2010). Skill and its material expression in the lithic manufacturing process also encompass a broad range of situations and micro-scale contexts. These factors would have affected not only whether unskilled knappers were permitted to experiment, sometimes tied with play (Ferguson 2008; Högberg 2008), but also to what varying degree the knapping activities of highly skilled knappers might have been present. Ethnographic data on contemporary stone adze production presented by Stout (2002) indicate that the variation in adze blades produced by skilled knappers is influenced by access to raw material. It appears necessary then for us to know more about the goal of production and differences in access to raw materials. Reconsidering environmental constraints and the context of human behavior is both interesting and challenging for an archaeological understanding of the skill learning process.

The lithic refitted sets derived from the Magdalenian assemblages in the Paris Basin show that the raw materials used in the production of blades and bladelets varied from large blocks or slabs measuring up to 70 cm long to small nodules of approximately 10 cm long. It seems that the variability of the morphological features in the raw materials originates in the different sources of flint within the Paris Basin (Audouze and Cattin 2011; Valentin et al. 2002). Several researchers (Abe 2004; Bodu et al. 1990; Grimm 2000; Karlin et al. 1993; Pigeot 1990) have argued that the selection of raw material itself generally depended on differences in the technical skill levels among knappers. A highly skilled knapper's ability is reflected from the beginning of the technological process, in that he tended to choose large blocks or slabs of fine quality as the raw material for blade knapping. Since searching for the sources of both large and fine-quality raw materials probably required a great deal of knowledge of the distribution of resources within the natural landscape, an apprentice knapper would not have had the same access to fine-quality raw materials, so tended to select small and low-quality nodules that ubiquitously distributed within the natural landscape. It is generally accepted that the correlation of raw material types with technological characteristics in Magdalenian assemblages, or in other assemblages, can be interpreted as representing differences in the competence of the knappers.

There is, however, no reason to suppose that the technical activities performed by Paleolithic knappers were invariable, regardless of what types of raw materials were used. It is worth questioning how technical skill levels were expressed materially if and when highly skilled knappers in the past were confronted with the need to exploit and use the various lithic raw materials available. Unfortunately, the important question of how knappers in the past dealt with the variety of raw materials, especially the variety of size and form, has been given little consideration. It is apparent that the relationship between the variety of available raw material and the criteria we use to identify technical skill levels should be further explored by analyzing suitable collections. Comparing refitted sets that show the original form of raw materials "packages", such as pebbles or debris within and/or between lithic assemblages, may be useful for resolving these issues.

9.3 The Shirataki Sites

The Shirataki sites are situated near Engaru, Eastern Hokkaido, Japan (Fig. 9.1). The sites lie around the upper stream of the Yubetsu River Basin, covering several square

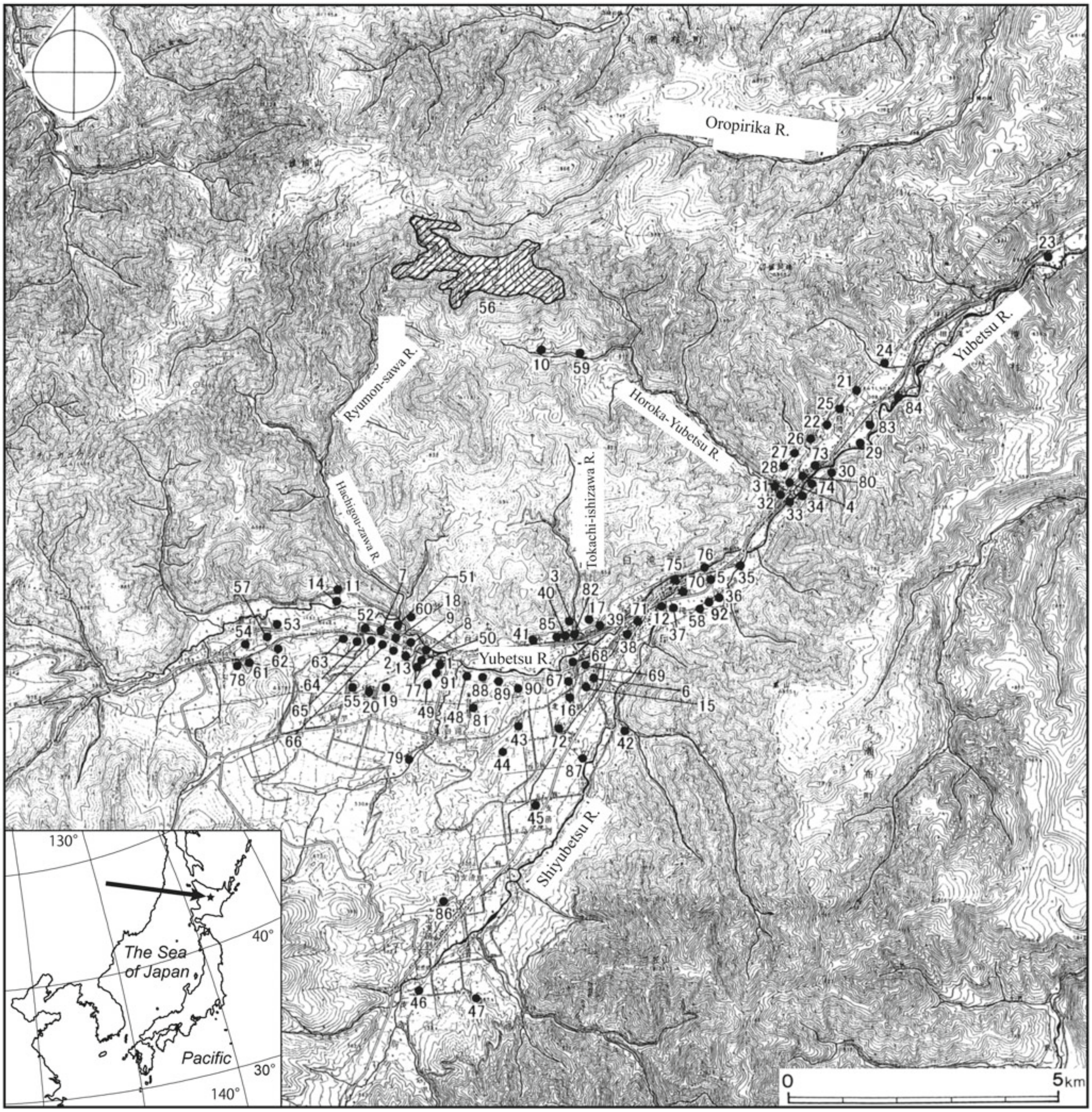


Fig. 9.1 Locations of the Paleolithic sites in Shirataki (modified after Suzuki and Naoe 2006). Hattoridai 2 site: 13, Kamishirataki 8 site: 91, Kamishirataki 2 site: 48, Akaishi-yama: 56

kilometers. Most of the Paleolithic sites known to us in Shirataki are topographically located along the margins of river terraces and hills, while a few sites have been identified in inaccessible mountain locations.

The sites identified around the upper stream of the Yubetsu River Basin have been repeatedly excavated by archaeologists since the 1950s. From a techno-typological point of view, most of the lithic assemblages obtained from the various sites in Shirataki belong to the Upper Paleolithic, and radiocarbon dating from some of the sites further supports this inference. Importantly, the Shirataki sites are located near a huge outcrop of obsidian that is of good quality, with few interior inclusions. The Upper Paleolithic inhabitants of the sites procured lithic raw materials from these local obsidian sources, and a large amount of lithic production was carried out at the sites. As Ferguson (2008) has suggested, it is probable that the closely related factors of raw material value and access were influential in determining how skill learning processes occurred in many contexts of prehistoric lithic production. In a situation where raw material is relatively abundant and of low value, a novice knapper may be permitted a degree of trial and error, either on his own or under the supervision of a skilled knapper. This matches the context of the Shirataki sites, where obsidian pebbles and debris favored for use as lithic raw material were abundant and could be easily acquired. Accordingly, it seems reasonable to expect that novice knapping activities could have occurred at these sites.

The excavations of the sites have yielded numerous stone artifacts suitable for describing and defining lithic reduction sequences, such as the Yubetsu method (Yoshizaki 1961), and they have allowed us to undertake detailed technological analyses of various microblade reduction sequences (e.g., Kimura 1992; Nakazawa et al. 2005). From a techno-typological perspective, studies of the Shirataki sites have focused on methods of tool manufacture used as time markers. Additionally, the materials from these sites have encouraged archaeologists to discuss an issue of truly international scope: the appearance and dispersal of pressure microblade production, which was regarded as a technical breakthrough of that time (Inizan 2012; Inizan et al. 1992; Takakura 2012).

It is necessary to note that most of the investigations at Shirataki before the 1990s involved relatively small areas and short-term excavations. However, since 1995 the Hokkaido Archaeological Operations Center has conducted lengthy investigations at Shirataki which are quite different from the previous excavations. The Center has extensively excavated 23 archaeological sites at Shirataki because of the construction of an expressway. The total area of excavation covers approximately 123,000 m^2 (Naoe 2012) and has resulted in the recovery of various lithic assemblages, including from the early to the late Upper Paleolithic. Large quantities of obsidian artifacts, mostly debitage, recovered from various findspots show that the sites were frequently occupied by prehistoric humans during the Upper Paleolithic and were related to the procurement and working of obsidian raw materials. The generally accepted view of the Upper Paleolithic hunter-gatherers in Hokkaido, Northern Japan, is that they were residentially mobile foragers wandering over a wide geographic area to exploit scattered resources in a cold and dry environment. The facts often cited in support of this are that the obsidian artifacts originating from the Shirataki sources are widely distributed in Hokkaido, and that lithic assemblages mainly comprised of these obsidian artifacts have been recovered from various other areas in Hokkaido, as far as 200–300 km from Shirataki (Kimura 1992; Nakazawa et al. 2005). Many analyses regarding the obsidian source provenance validate this inference.

The recent investigations have managed to fully document the spatial distributions of the stone artifacts in the sites, and consistently refit stone artifacts in the various lithic assemblages (e.g., Naganuma et al. 2000; Naoe 2012). Both matters had not been fully explored until then. The majority of the lithic assemblages from the Shirataki sites are made up of locally available obsidian, which often exhibits considerable macroscopic variation from one piece to another, and therefore helps in the refitting of a great deal of manufacturing debris and stone tools.

It is important that the refitting of artifacts leads to an assessment of the integrity of context and the degree of movement of each artifact, and on occasion enables an assessment of an approximate span of time that the assemblage represents. Moreover, refitting studies assist archaeologists in developing detailed technological analyses of lithic reduction sequences, especially of what raw materials were selected and how methods and techniques were followed by knappers in the past. Undoubtedly, new discoveries have been made at the Shirataki sites that not only alter our techno-typological understanding of Upper Paleolithic assemblages in Hokkaido, but also expand the potential of lithic refitting for the evaluation of prehistoric human behavior (e.g., Naoe 2003; Suzuki 2007; Takakura 2010).

The archaeological records at Shirataki, like those of other Paleolithic sites in Hokkaido (Nakazawa et al. 2005), have been subject to disturbance by non-human forces. Small scale reworking, perhaps due to solifluction, is common throughout the Upper Paleolithic sites at Shirataki. This leads to the downslope movement of stone artifacts on the exposed surfaces, and this process would have altered the distributions of the archaeological materials to some extent. Nevertheless, it has not crucially impacted the integrity of the context on a scale requiring discussion in this paper, because the patterning of the refitted stone artifacts, especially manufacturing debitage, generally follows the spatial clustering at the sites.

The lithic refitted pieces obtained from the Shirataki sites are unique in the Upper Paleolithic record in Japan in three respects. First, numerous refitted pieces have been recognized from each of the assemblages, offering a wealth of technological information on the production of blades, microblades, bifaces, and boat-shaped tools. This allows us to compare refitted pieces within lithic assemblages that are supposed to represent an identical cultural tradition. The procedure for such comparisons may prove a useful way of considering unevenly expressed skill levels within certain assemblages, in order to explain the skill learning process among knappers in the past.

Second, many obsidian refitted artifacts have been recognized, conjoined with a quantity of stone tools and debitage, and some of these have been reconstructed nearly to the level of the original nodule or slab of raw material. These materials can contribute to an understanding of the morphological features of cobble and lithic debris originally selected for use as raw material by the knappers. This is important because we need a better grasp of the relationship between raw materials and certain attributes regarded as skill signatures in previous studies.

Third, we can assess the spatial distributions of refitted lithic artifacts within the sites, although these have been, to some extent, modified by natural transformation processes such as solifluction. Analyzing these distributions is critical to answering questions about skill learning processes, as it highlights how the distribution of analyzed refitted lithic artifacts relates to prehistoric human behavior at the sites.

9.4 Analyzing Refitted Sets from the Shirataki Sites

9.4.1 Criteria for Identification of Technical Skill Levels

I focus here on the skill learning processes reflected in refitted sets concerned with blade reduction. This study follows Andrews (2003), Audouze and Cattin (2011), Bodu et al. (1990), Clark (2003), Johansen and Stapert (2008), Karlin et al.(1993), Naoe (2003), Pigeot (1987, 1990), and Shelley (1990) in considering some of the technological characteristics observed in the refitted sets as a key to understanding technical skill levels. The most well-known studies concerned with such an approach, as mentioned above, have been carried out in the Magdalenian open-air sites in the Paris Basin. A technological analysis of flint knapping at these sites shows that, to a certain extent, three levels of skill—expert knappers, advanced learners, and beginners—can be recognized in the refitted flint evidence. At Étiolles U5 in particular, up to six or seven levels of skill were distinguished (Olive 1988; Pigeot 1987, 1990). Such research also revealed that the unskilled knappers tended to work in locations that were peripheral to the hearth-centered activity zones, whereas the skilled knappers tended to conduct their knapping activities around the hearths.

These studies have also highlighted some of the qualitative evidence indicative of the activities of highly skilled knappers, including high productivity of blades, regularity of the form of the blades, careful preparation and maintenance of the core volume especially when rejuvenating the platform and ridge, patterned multistage reduction sequences, appropriate restoration of errors such as hinge fracture terminations (e.g., Naoe 2003; Shelley 1990), and precise application of force. Other evidence is characteristic of the activities of novice knappers, including low productivity of blades, irregularity of the form of the blades, failure to rejuvenate, wasteful and ineffectual use of raw materials, and misapplication of force, especially resulting in face battering and stacked steps (Johansen and Stapert 2008; Shelley 1990). Of course, we cannot necessarily assume that such features in the particular refitted sets can always be observed systematically. A dichotomization of skill among prehistoric knappers is obviously too simplistic to apply to the varied archaeological evidence. At the least, we must also consider a medium level of skill, for example, the advanced learner with a modest productivity (Johansen and Stapert 2008).

In addition, of particular concern in this paper is the behavioral context of knapping activities and the technological needs relevant to evaluating skill learning processes. Therefore, I attempt to assess not only the technological characteristics that have been generally interpreted as skill signatures in previous approaches, but also the presence/absence of blade cores, as well as the degree of absence of blades, among the refitted sets. The former is a matter of whether the blade cores we expect to be included in the refitted sets are recovered from the site or not. The latter refers to a comparison between the estimated number of produced blades and the estimated number of missing blades in the refitted sets. Because recent excavations at the Shirataki sites have been conducted extensively, and refitting of the recovered stone tools and debitage was careful and patient, the presence or absence of blades and blade cores in the refitted sets can provide useful and reliable information for evaluating the behavioral context of knapping activities (e.g., Suzuki 2007). These phenomena are related to the notion of the "ghost", a term coined by Morrow (1996) to refer to how artifacts are taken away from a site while the manufacturing debitage remains and can be refitted. Morrow stressed that this was correlated to the site occupation span.

The approach presented here is based on the combination of two indicators, namely the presence/absence of blade cores and the degree of absence of blades, which may be connected with the levels of technical skill the prehistoric knappers had, and the behavioral contexts in which knapping occurred. Because the Upper Paleolithic hunter-gatherers in Hokkaido were residentially mobile foragers who adapted to a cold and dry environment (e.g., Kimura 1992; Nakazawa et al. 2005; Takakura 2012), they may have needed to reduce the transportation burden of their tool kits and blanks in order to reduce the costs of residential moves. To supplement the kits and blanks systematically, mobile hunter-gatherers of the Upper Paleolithic repeatedly visited Shirataki. They likely acquired and processed obsidian raw materials for the production of portable blanks and stone tools. Needless to say, not all of the blanks and tools produced at Shirataki were necessarily taken away from the Shirataki sites. Generally speaking, well-made blade cores and blades were exported from the Shirataki sites with expectation of their further use as blanks or tools. These artifacts were more likely to be products of expert knappers. In contrast, the majority of the products knapped by novices were left where they were struck, supporting the hypothesis that these scatters represent simple training exercises (Bodu et al. 1990).

Of course, we clearly need to consider whether this prediction is applicable or not. Blade cores were likely abandoned at

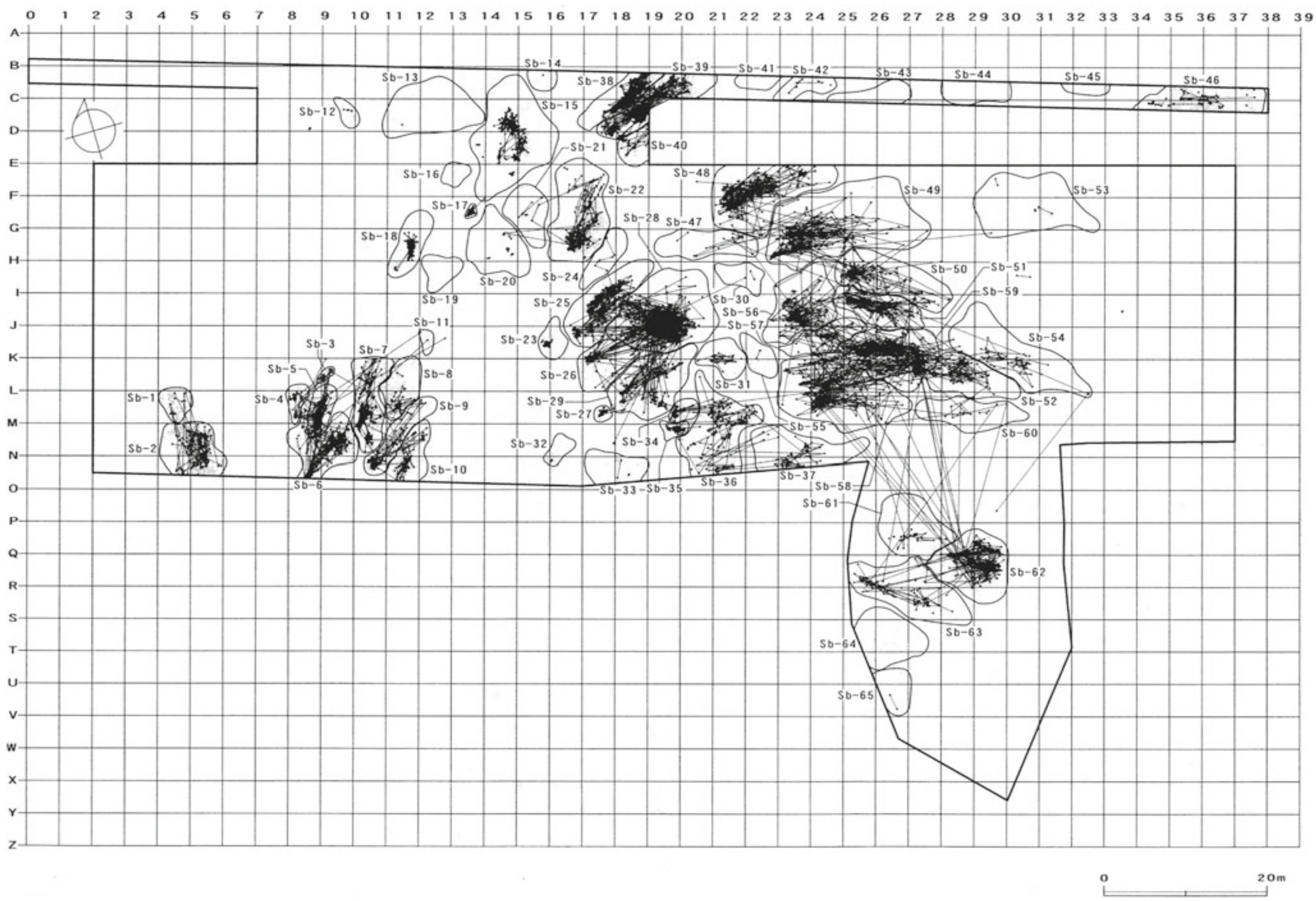


Fig. 9.2 Distributions of stone artifacts in the Hattoridai 2 site (Naoe 2007). Note the connecting lines among the small dots show that they are refitted

the site when significant accidental flaking occurred (e.g., due to inferior inclusions or joint surfaces in the obsidian pieces) and such an error would have simply stopped the operational sequences. However, in other cases, they may have been abandoned for economic reasons: work stopped when the core was found to be too small to create the final product (e.g., Karlin and Julien 1994). Without knowing more details about the results of flaking that might have led to abandonment, we cannot automatically regard the presence of blade cores as an indicator of prehistoric knappers' skill level. If we find an inconsistency between the presence/absence of blades, as well as of blade cores, and the technical skill level recognized through the technological skill signatures, we should look for a different interpretation of the knappers' behavior.

Below, I present data documenting the skill levels and learning processes obtained from three Shirataki sites: the Hattoridai 2 site, the Kamishirataki 8 site, and the Kamishirataki 2 site.

9.4.2 The Hattoridai 2 Site

The Hattoridai 2 site was excavated from 1998 to 2000 (Naoe 2007). The excavations revealed the presence of Upper Paleolithic cultural strata lying 20 to 50 cm below the present surface. The number of artifacts recovered from the site is 798,648, and all materials represent the late Upper Paleolithic period from a techno-typological point of view. The total area of excavation covers 6,691 m^2. A total of 53 spatially discrete artifact concentrations have been identified (Fig. 9.2): these have been grouped into 28 units according to similarity in lithic technological characteristics observed in the recovered artifacts and the intra-site spatial patterning of refitted sets. Each of the units may be understood to represent a distinct cultural component. Here, I focus on the lithic assemblages obtained from the unit concentration Sb-23–31 because there is rich information to be derived from the refitting of stone artifacts. While the spatial distribution of this concentration may, to some extent, be modified by post-depositional agents such as solifluction, the spatial patterning of the refitted sets shows that this concentration is useful for understanding the processes in knapping activities.

The assemblage from concentration Sb-23–31 consists of side-scrapers, end-scrapers, gravers, boat-shaped tools, blades, blade cores, flakes, chips, and various types of bifaces. Blades are used as blanks for these flake tools. All of the flake tools are made of obsidian which mostly came from

Table 9.1 Refitted sets from concentration Sb-23–31 at the Hattoridai 2 site

No.	Raw material	Size (cm)	Weight (g)	Blade core	Number of recovered blades	Total number of refitted pieces
153	Angular gravel	31×17×27	3,745	Absent	12	272
130	Sun-angular gravel	27×17×11	1,451	Absent	15	151
129	Sun-angular gravel	22×16×10	1,847	Absent	2	45
128	Round gravel	26×16×23	6,676	Present	5	98
203	Round gravel	30×11×19	6,595	Present	0	15

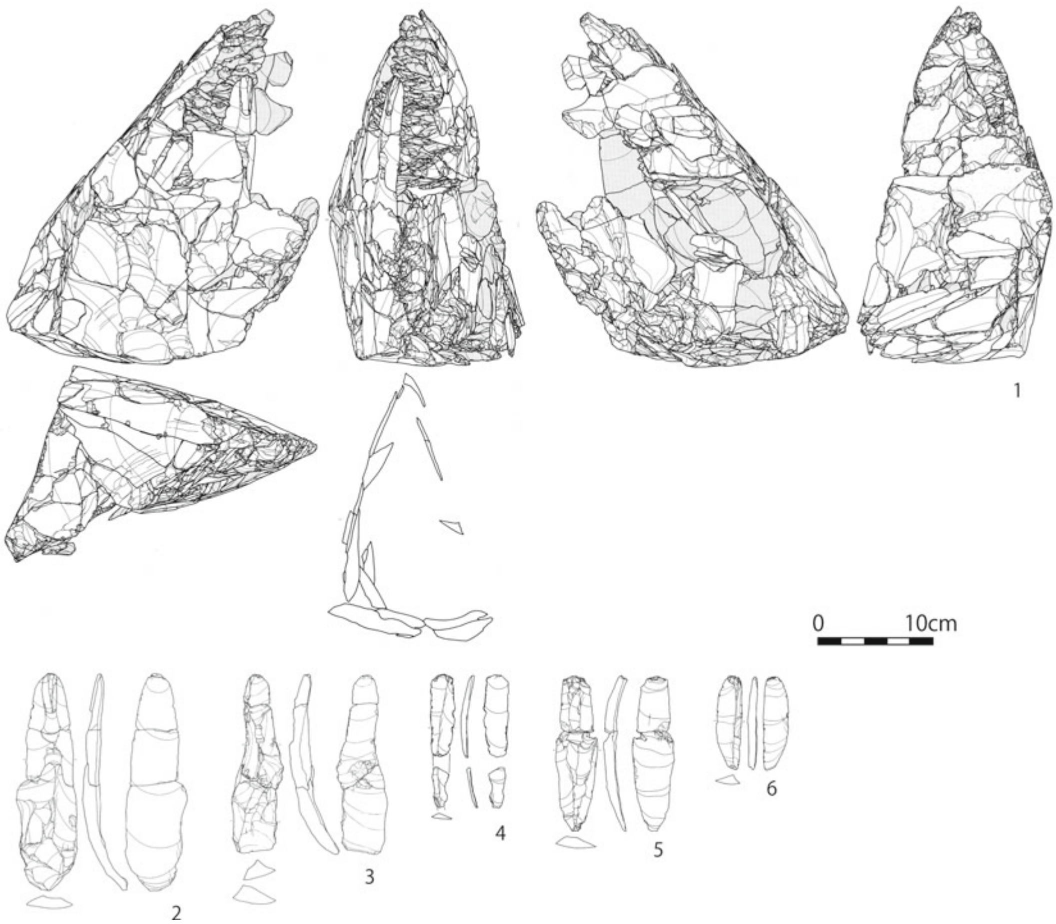


Fig. 9.3 Refitted set No. 153 from the Hattoridai 2 site (1) (Naoe 2007). *1*: refitted set, *2–6*: blades included in the refitted set No. 153

Shirataki. The assemblage from concentration Sb-23–31, consisting of co-occurring sets of identical morphological and technological traits, indicates little reason to suspect mixing with other assemblages. Persistent refitting efforts among this assemblage provide several refitted sets that can describe the detailed processes of blade and bifacial reduction. In addition, the roundness of the natural cortex observed on the dorsal surface of lithic artifacts demonstrates that angular, sub-angular, and rounded obsidian cobbles were used to produce the blades. The assemblage is therefore suitable for elucidating the relationship between the morphological features of lithic raw material "packages" and the technological features of reduction sequences.

In this assemblage, the lithic refitted artifacts derive from both bifacial and blade reduction. Twelve of the refitted sets represent bifacial reduction, conjoining with many flakes. The bifacial reduction sequences from concentration Sb-28 were distinctively executed. In contrast, five of the refitted sets display comprehensive blade reduction sequences, conjoining with blades, blade cores, and flakes. The refitted sets related to blade reduction were mostly recovered from concentrations Sb-25, 26, and 28.

A difference in the morphological features of raw materials used for blade reduction can be recognized within the refitted sets. Angular and sub-angular obsidian cobbles were used as raw material in refitted sets No. 153, 130, and 129, whereas rounded cobbles were used in refitted sets No. 128 and 203. Table 9.1 shows a description of these refitted sets.

From a comparison of several technological features related to skill signatures, the refitted sets No. 153 (Fig. 9.3)

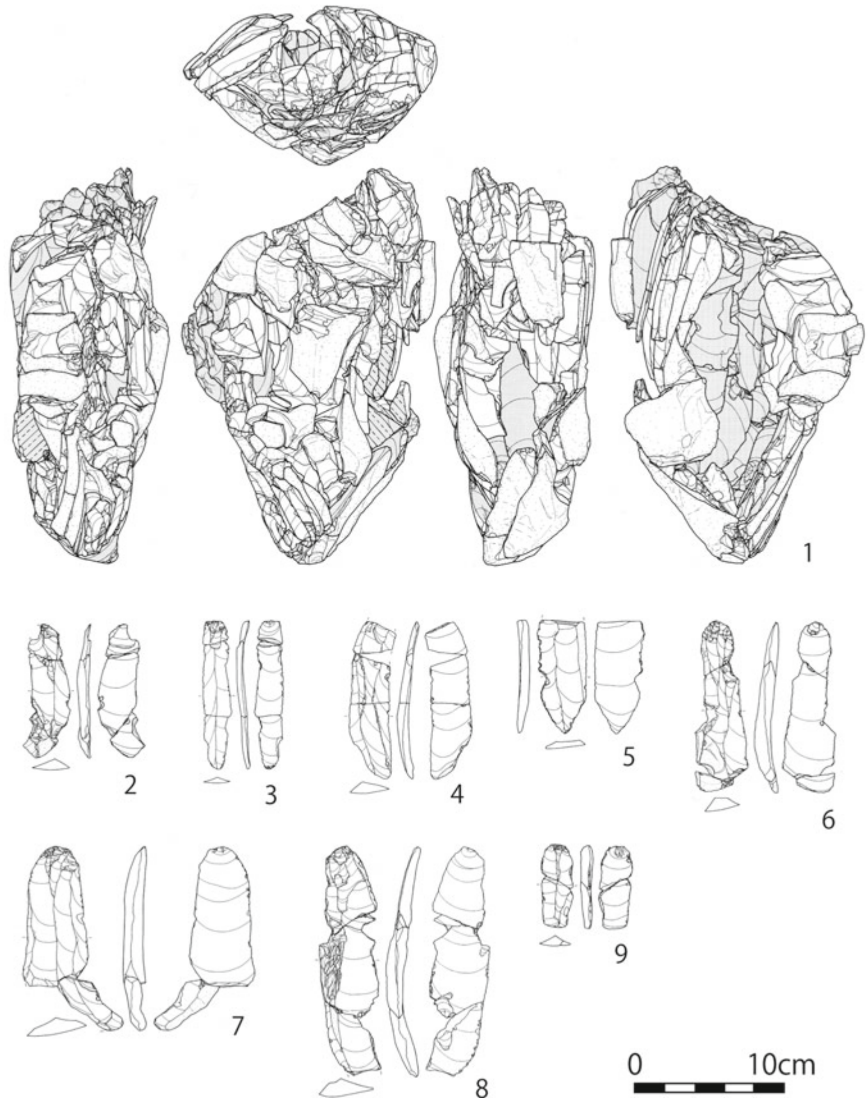
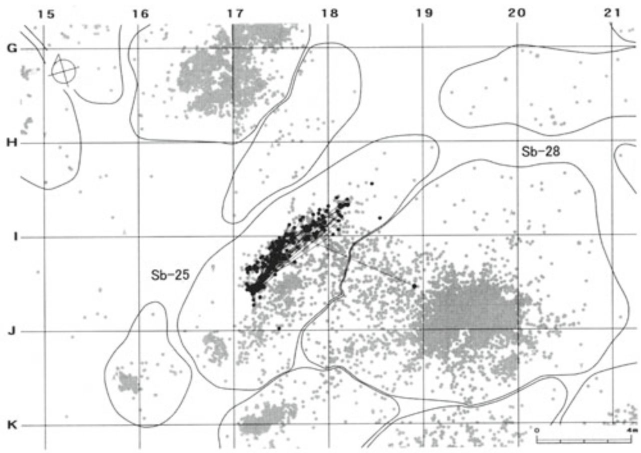


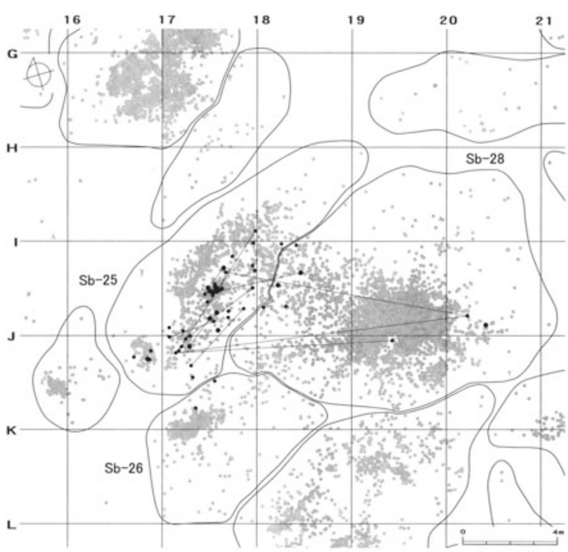
Fig. 9.4 Refitted set No. 130 from the Hattoridai 2 site (2) (Naoe 2007). *1*: refitted set, *2–8*: blades included in the refitted set No. 130

and 130 (Fig. 9.4) can be interpreted as having been produced by a skilled knapper. Both cases show that the prepared blanks of cores were imported to the site and used for the blade production. The cores were prepared and rejuvenated carefully by cresting over the full length of the production face and faceting the striking platform, and thus the proper angle between the striking platform and the production face was maintained. Thin and side-paralleled blades were subsequently produced from the production face. Few misapplications of force can be seen in either of the refitted sets. Neither of the blade cores in both refitted sets was recovered from this site. Additionally, there are very few blades associated with these refitted sets. In general, concentration Sb-25 (Fig. 9.5), from which these two refitted sets came, is characterized by a scarcity of blade cores and blades.

In contrast, the refitted sets No. 128 (Fig. 9.6) and 203 (Fig. 9.7) can be interpreted as resulting from a knapper with a low level of technical skill, such as a novice knapper. The imported core blanks were less prepared in comparison with those in the expert concentrations. Bulbs of percussion observed on these refitted sets tend to be more strongly marked. Flaking resulted in thick remnants with hinge or step terminations, because of misapplications of force. In addition, the knappers of these materials failed to produce and maintain either the proper platform angle or the effective production face for the systematical blade production. The reduction processes progressed unsystematically and irregular blades were produced, with an overall low level of productivity. In these two cases, almost all of the products, including cores, blades, and flakes, are



Refitted set No.153



Refitted set No.130

Fig. 9.5 Distributions of the refitted sets No. 153 and 130 in the Hattoridai 2 site (Naoe 2007). Note: all artifacts are represented by *light black dots*. The *darker black dots* indicate that they were likely originated from an identical analytical core unit, identified based on the color, texture and inclusion. The *connected lines* among the *darker dots* show that they refit together

refitted and were recovered from concentrations Sb-26 and 28 (Fig. 9.8).

Some, but not all, technical elements relevant to the identification of a skilled knapper can be partially observed in the refitted case No. 129 (Fig. 9.9), which was recovered from concentration Sb-28 (Fig. 9.10). The blade core that appear to have been produced from this material was exported from the site. Therefore, No. 129 can be identified as the product of a knapper with medium-level competence, such as an advanced learner.

Comparison of the refitted sets indicates a strong similarity between archaeological skill signatures and the presence/absence of blade cores and blades. In this case, distinguishing whether blade cores and blades are present in the refitted artifacts may provide fruitful insights into the important characteristics of technical skill levels for producers of Paleolithic artifacts. Moreover, a comparison of the refitted artifacts reveals that different skill levels among the knappers are associated with the selection of raw materials: whereas the skilled knappers seem to have used angular and subangular obsidian cobbles as starting points for blade production, the less skilled knappers used rounded obsidian cobbles. In the case of this assemblage, there is no difference in size between the angular and rounded cobbles used for blade production. Consequently, based on the various information presented above, we can understand that the skill of prehistoric knappers in this concentration was involved in the selection of the form of raw materials, even when the technological ends were the same.

It is noteworthy that the distributions of refitted artifacts made by the skilled knappers and novice knappers are spatially distinct in this assemblage. This is valuable patterning because it can give clues to the relationships between multiple knappers with different levels of skill. In spite of limited data showing that knapping activities in this assemblage were conducted simultaneously, a distinction in the spatial patterning implies that the activity zones of the skilled knappers and novice knappers were differentiated based on well-defined spatial rules, and that such rules might therefore have been recognized by both types of knappers. It is difficult to infer from this that the experts and the beginners conducted their knapping activities at the same spot. Probably both paid attention to the other's knapping activities, either explicitly or implicitly. This would have provided favorable conditions for observational learning of knapping operations and skills. Thus, the novice knappers would have been encouraged to learn on their own, through experimental knapping activities as training exercises, but sometimes tied with observation of the skilled knappers.

This patterning is nevertheless different from that of the Paris Basin, where the best places around the hearth were reserved for skilled knappers and the apprentices were kept outside the domestic space (Audouze and Cattin 2011; Pigeot 1990). The case of the Hattoridai 2 site at least suggests that the relationship between skilled knappers and novice knappers was not spatially hierarchical.

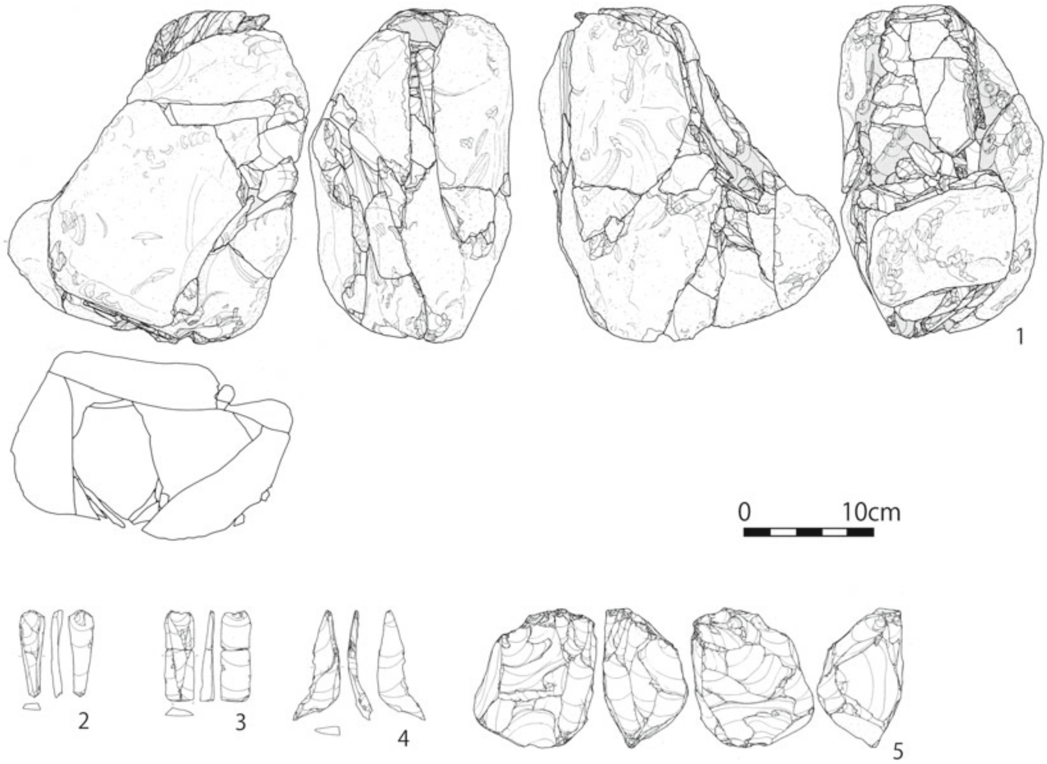


Fig. 9.6 Refitted set No. 128 from the Hattoridai 2 site (4) (Naoe 2007). *1*: refitted set, *2–4*: blades included in the refitted set No. 128, *5*: core included in the refitted set No. 128

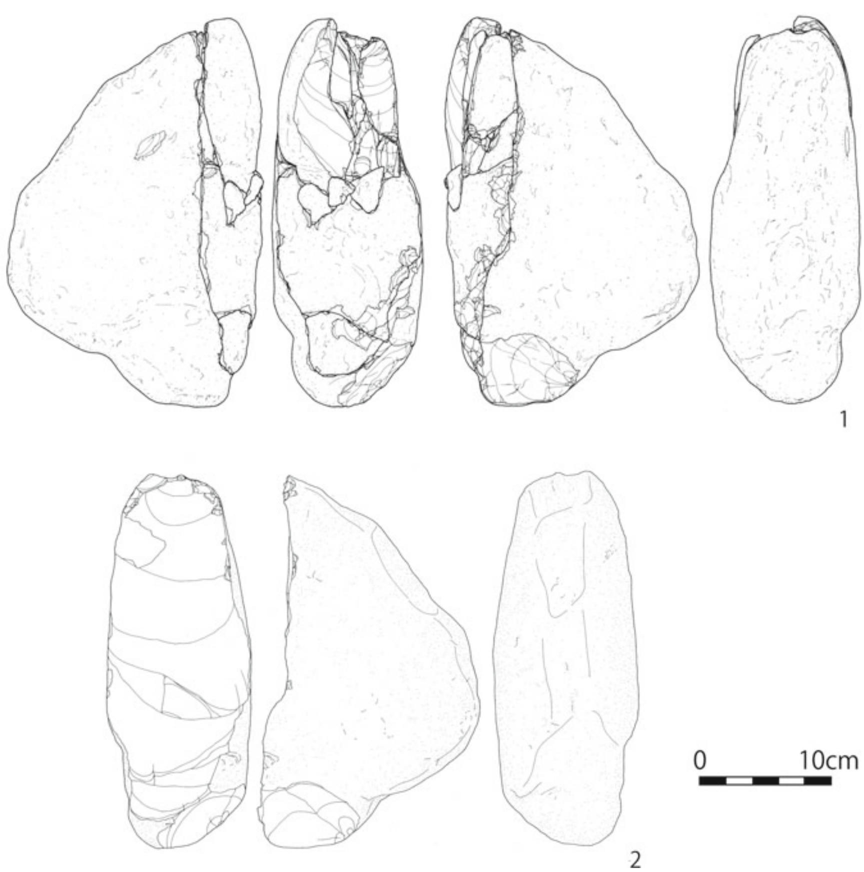


Fig. 9.7 Refitted set No. 203 from the Hattoridai 2 site (5) (Naoe 2007). *1*: refitted set, *2*: core included in the refitted set No. 203

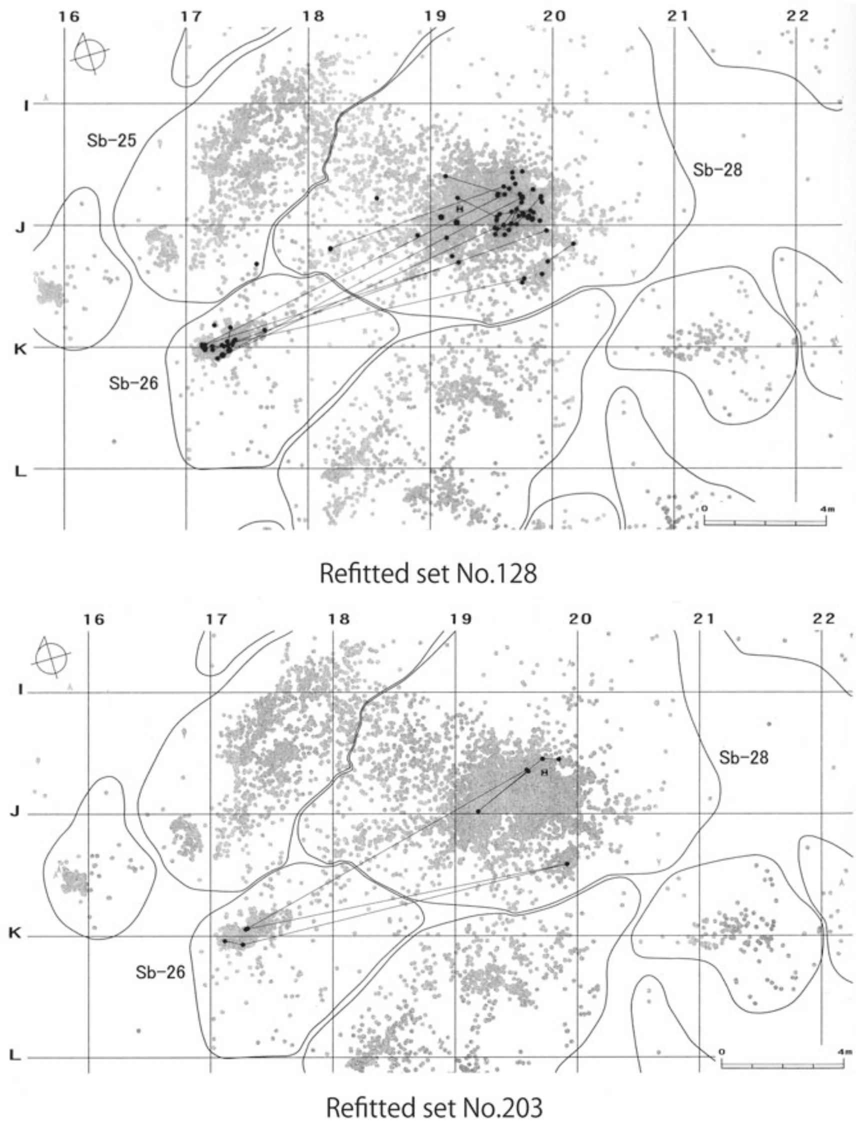


Fig. 9.8 Distributions of the refitted sets No. 128 and 203 in the Hattoridai 2 site (Naoe 2007). Note: all artifacts are represented by *light black dots*. The *darker black dots* indicate that they were likely originated from an identical analytical core unit, identified based on the color, texture and inclusion. The *connected lines* among the *darker dots* show that they refit together

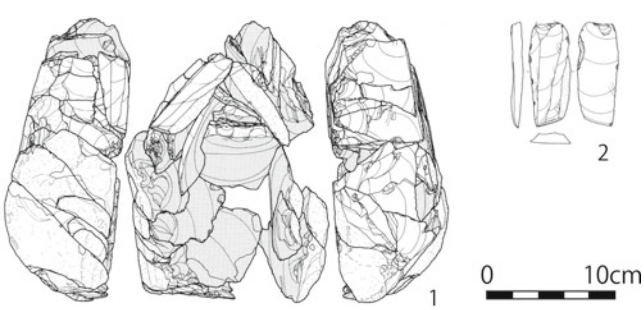


Fig. 9.9 Refitted set No. 129 from the Hattoridai 2 site (Naoe 2007). *1*: refitted set, *2*: blade included in the refitted set No. 129

9.4.3 The Kamishirataki 8 Site

The Kamishirataki 8 site was excavated between 1995 and 2000 (Suzuki and Naoe 2006). The artifacts recovered number 1,354,567, and these appear to be multiple components from the early Upper Paleolithic to the late Upper Paleolithic, both from techno-typological evidence and from some available radiocarbon dates. This demonstrates that the site was repeatedly occupied during the Upper Paleolithic period. The total area of excavation covers 17,849 m^2, and 111 artifact concentrations have been identified, based on the spatial distribution of the artifacts and their refitting patterns.

Here, I focus on the lithic assemblage from concentration Sb-90 as it contained several refitted artifacts related to blade production, providing us with a wealth of information on blade reduction sequences as well as on the knappers' technical skill levels. Concentration Sb-90 is spatially discrete from other concentrations. This concentration may be understood to represent a distinct cultural component, because the distribution of the refitted artifacts is limited within this concentration. The assemblage also shows several major technological features, suggesting little mixing with other assemblages.

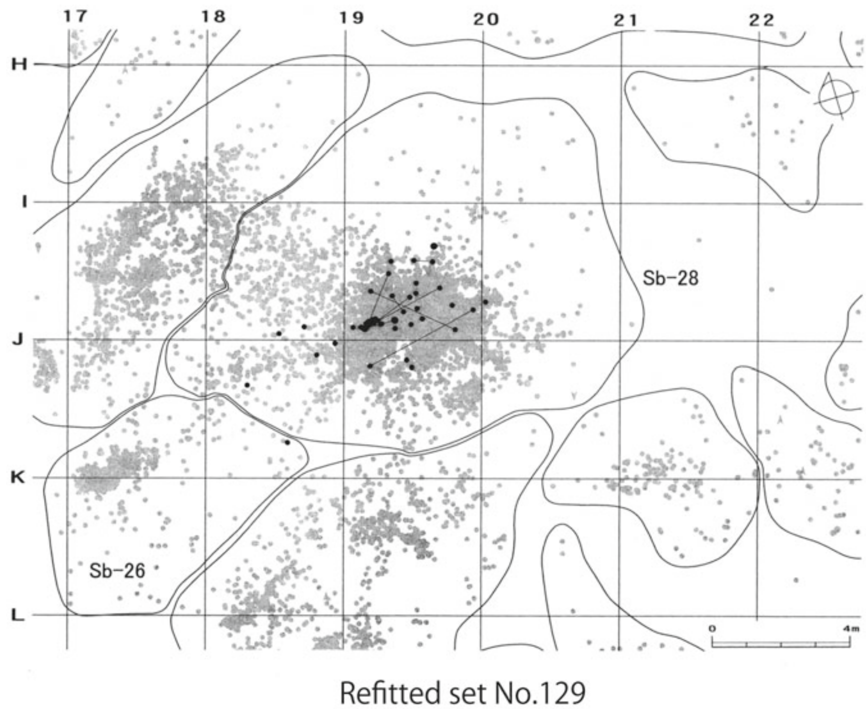


Fig. 9.10 Distributions of the refitted set No. 129 in the Hattoridai 2 site (3) (Naoe 2007). Note: all artifacts are represented by *light black dots*. The *darker black dots* indicate that they were likely originated from an identical analytical core unit, identified based on the color, texture and inclusion. The *connected lines* among the *darker dots* show that they refit together

The assemblage from concentration Sb-90 contains an abundance of chipped stone manufacturing debris and also contains side-scrapers, end-scrapers, gravers, boat-shaped tools, blades, blade cores, cores, and microblade cores. With only a few exceptions, these are made of obsidian available at Shirataki. The Oshorokko type of microblade core (Nakazawa et al. 2005; Takakura 2012) can be recognized in this assemblage. A techno-typological comparison reveals that this assemblage belongs to the late Upper Paleolithic (Suzuki and Naoe 2006). Unfortunately, no chronometric dates have been obtained to give a reliable chronological position for this assemblage.

Large numbers of flakes, blades, and blade cores from concentration Sb-90 are successfully conjoined (Figs. 9.11 and 9.12). These show that the cobbles used in blade reduction sequences are variable, particularly in relation to form, including angular, sub-angular, and rounded forms. These cobbles may have been acquired near the site. Here, I attempt to examine eight refitted sets relevant to blade reduction, reconstructed of nearly original raw material forms, and distributed within lithic concentration Sb-90. The maximum length of the angular and sub-angular cobbles used as raw materials is slightly larger than that of the rounded cobbles. Angular and sub-angular cobbles were used in refitted sets No. 693 (Fig. 9.11: 1), 690 (Fig. 9.11: 2), 688 (Fig. 9.11: 3), and 704 (Fig. 9.11: 4), whereas rounded cobbles were used in refitted sets No. 691 (Fig. 9.12: 1), 699 (Fig. 9.12: 2), 700 (Fig. 9.12: 3), and 689 (Fig. 9.12: 4). Descriptions of these raw materials are summarized in Table 9.2.

Careful preparation, as well as repeated rejuvenations of the striking platforms and the ridges of blade cores, can be recognized in all of the refitted sets. Blade removal is unidirectional with an adapted oblong volume, with rubbing on the pecked platform, presumably with the aid of abrasives. Slender and regular blades were frequently detached (Fig. 9.13). Although the morphological features of the obsidian cobbles vary among these refitted sets, the technological characteristics observed in the blade reduction process and its products are surprisingly similar. Also, there are few differences in the technological evidence of skill signatures among these refitted sets. Consequently, it is difficult to identify any differences in the technical skill level of the knappers, in spite of the variability that can be seen in the morphological features of the raw materials. This evidence suggests that the knappers involved in the formation of this assemblage at the Kamishirataki 8 site had equivalent skills in blade production. They used various forms of obsidian cobbles as raw materials to remove the blades, in contrast to the situation at the Hattoridai 2 site.

Blade cores are present in all these refitted sets except No. 693 and 689 (Fig. 9.13). Conversely, the vast majority of blades that appear to have been detached were exported from the site. These are the "ghosts" in this assemblage. Therefore, there is an inconsistency between blade cores and blades. Interestingly, unusual flaking accidents, such as hinge fracture scars and other irregularities, usually occurred just before abandonment, especially conjoined with the blade cores (Suzuki and Naoe 2006). Such accidental flaking might have

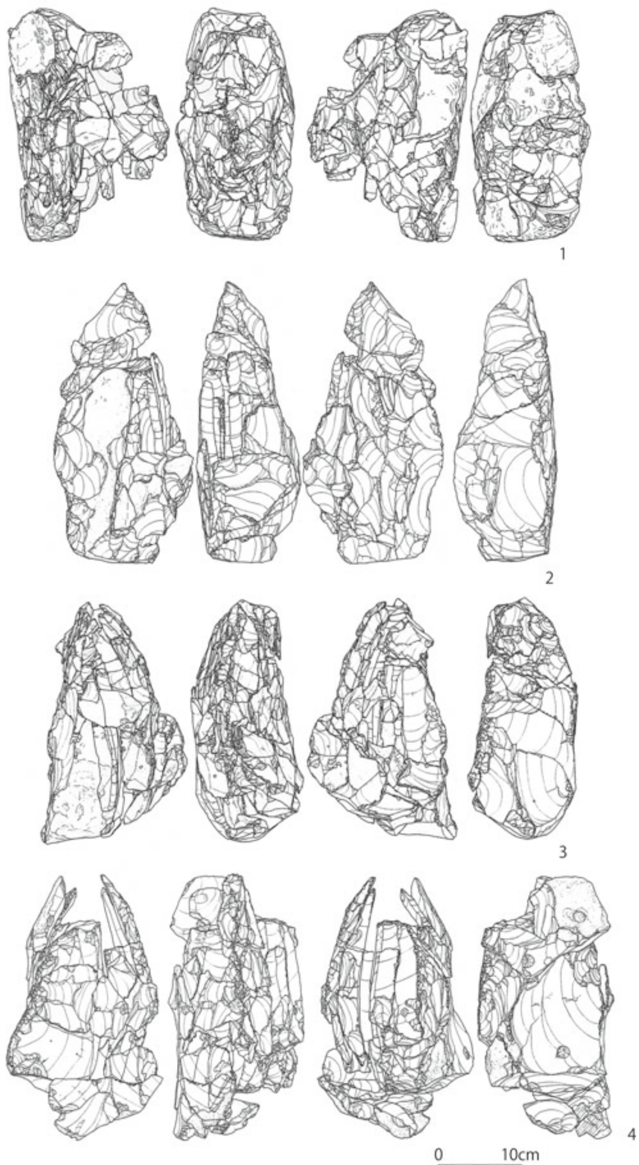


Fig. 9.11 Refitted sets from the Kamishirataki 8 site (1) (Suzuki and Naoe 2006). *1*: No. 693, *2*: No. 690, *3*: No. 688, *4*: No. 704

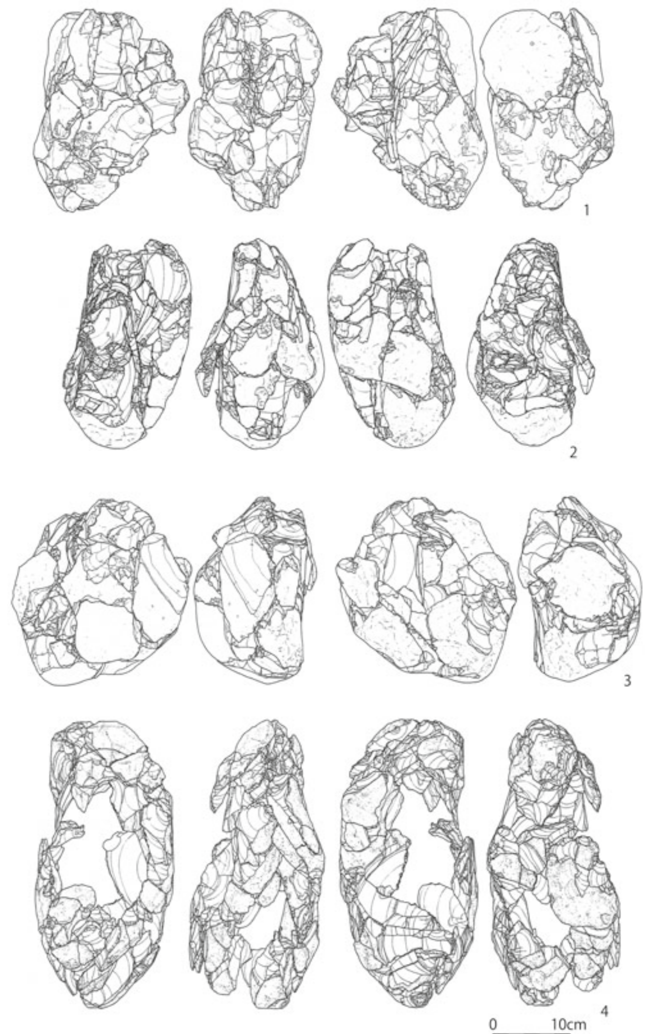


Fig. 9.12 Refitted sets from the Kamishirataki 8 site (2) (Suzuki and Naoe 2006). *1*: No. 691, *2*: No. 699, *3*: No. 700, *4*: No. 689

Table 9.2 Refitted sets from concentration Sb-90 at the Kamishirataki 8 site

No.	Raw material	Size (cm)	Weight (g)	Blade core	Number of recovered blades	Total number of refitted pieces
693	Sub-angular gravel	29 × 19 × 15	2,995	Absent	9	176
690	Angular gravel	35 × 17 × 13	5,342	Present	5	36
688	Angular gravel	30 × 17 × 13	4,181	Present	12	78
704	Sub-angular gravel	33 × 19 × 17	5,846	Present	4	33
691	Round gravel	27 × 19 × 16	5,486	Present	4	59
699	Round gravel	28 × 17 × 15	4,795	Present	7	89
700	Round gravel	26 × 22 × 16	5,916	Present	2	40
689	Round gravel	27 × 19 × 16	3,266	Absent	11	120

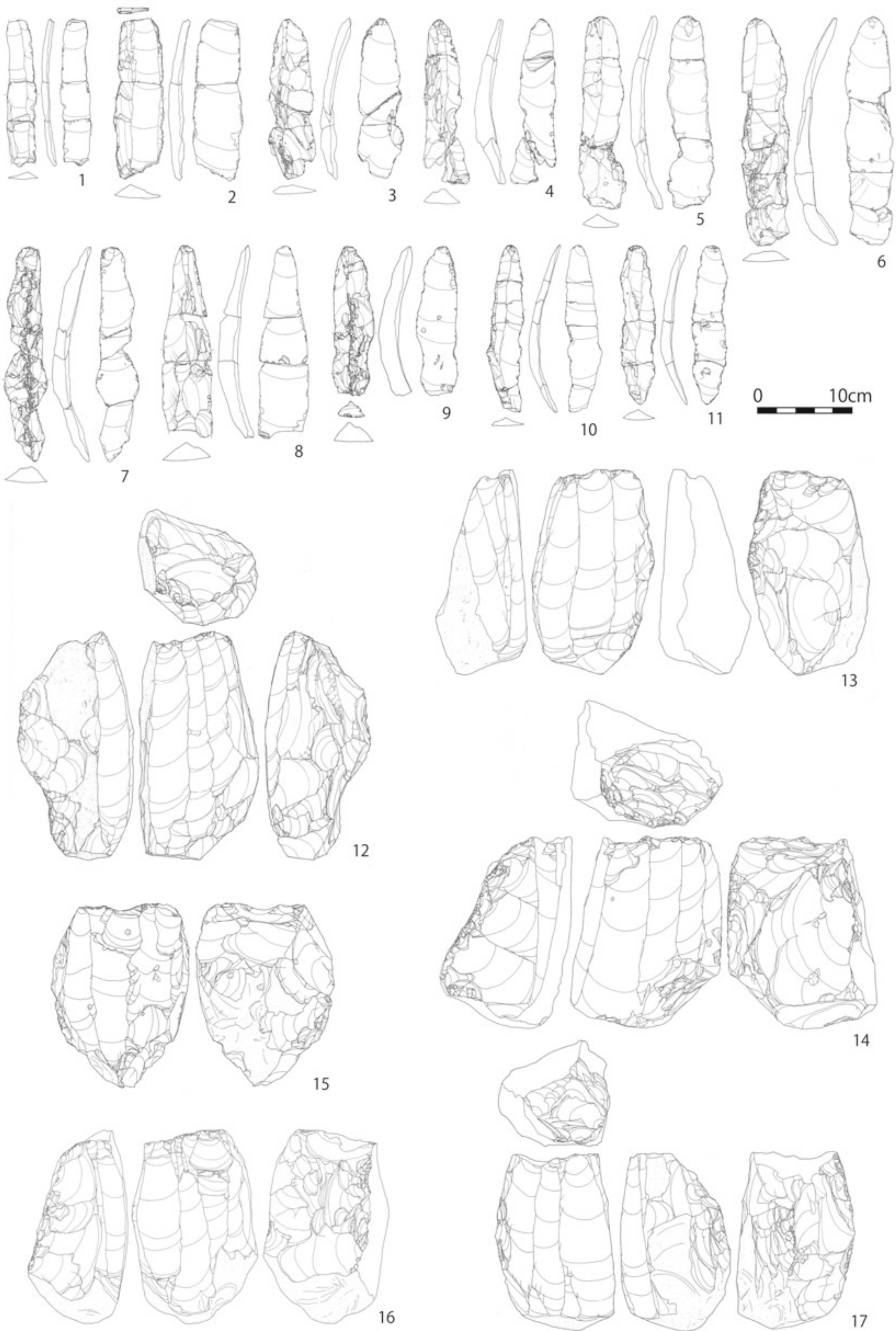


Fig. 9.13 Blades and Blade cores from the Kamishiratake 8 site (Suzuki and Naoe 2006). *1–2*: blades (No. 690), *3–6*: blades (No. 688), *7–8*: blades (No. 704), *9–11*: blades (No. 691), *12*: blade core (No. 690), *13*: blade core (No. 688), *14*: blade core (No. 704), *15*: blade core (No. 691), *16*: blade core (No. 699), *17*: blade core (No. 700)

resulted in the abandonment of cores at the site. The evidence obtained from this site demonstrates that skill signatures are clearly associated not with the absence of blade cores but with the absence of blades. Because the presence/absence of cores may be sometimes influenced by unusual flaking accidents, we should instead pay attention to missing blades among the refitted sets for the evaluation of technical skill levels.

There are no refitted sets that seen to reflect different levels of technical skill from concentration No. 90 at the Kamishirataki 8 site, in contrast to the case at the Hattoridai 2 site. As far as the technological features among the refitted sets show, it is probable that one or more skilled knappers manufactured blades at this spot. In other words, there is no evidence of the result of training exercises performed by novice knappers at this spot.

9.4.4 The Kamishirataki 2 site

The Kamishirataki 2 site was excavated from 1996 to 1997 by the Hokkaido Archaeological Operations Center (Naganuma et al. 2001). A total of 15 artifact concentrations have been identified and 432,429 tools and debitage items recovered. These artifacts are mostly debitage made of obsidian locally available at Shirataki. However, a few artifacts made of hard shale, chert, andesite, mudstone, and agate have been recovered. This site contains multicomponents from the middle to late Upper Paleolithic. The total area of excavation covers 6,925 m^2.

Here, I focus on the lithic assemblage from concentration Sb-9, which is spatially distinct from other concentrations (Fig. 9.14). Also, the distribution of the refitted artifacts is limited within this concentration. Other concentrations in this site appear to belong to a different cultural tradition. The assemblage from concentration Sb-9 includes gravers, end-scrapers, side-scrapers, microblades, microblade cores, blades, flakes and chips. Almost all of these artifacts are made of obsidian. The microblade cores can be typologically characterized as of the Hirosato type (Nakazawa et al. 2005; Takakura 2012). Although AMS 14C dating was not obtained from this concentration, a techno-typological evaluation on the assemblage revealed that it belongs to the late Upper Paleolithic (Naganuma et al. 2001).

There are four refitted sets No. 142 (Fig. 9.15: 1), No. 136 (Fig. 9.15: 2), No. 137 (Fig. 9.16: 1), and No. 124 (Fig. 9.16: 2) relevant to the manufacture of large blades. Descriptions of these are presented in Table 9.3. Each of them, conjoining with many blades and flakes, clearly shows how the raw materials were selected, how there was repeated preparation and rejuvenation of the blade cores, and subsequently which blades were removed. It appears that blade production of these refitted sets progressed in much the same manner.

First, large chunks of obsidian debris were commonly used as raw material, and they show sufficiently good quality for blade production. The diameters of chunks selected in this assemblage average about 40 cm. Second, formal and long blades, from almost 10 cm up to 30 cm in length, were subsequently detached during these blade reductions (Fig. 9.17). Such detachment requires multistage reduction sequences, including careful preparation and several rejuvenation stages that involve striking the platforms as well as the ridges on the blade cores. Blade removal of these refitted sets was generally executed from one striking platform—occasionally from opposed striking platforms—with one front crest. These were always connected through rubbing on the pecked platform, presumably with the aid of abrasives. Third, when hinge fracture terminations accumulated on the production face of the cores as well as the striking platforms, the knappers often rejuvenated the flaking surfaces and platforms to eliminate the accumulated errors. After that, the detachment of blades was re-initiated on the cleaned-up flaking surfaces.

Therefore, the technological features common to all of the blade refitted sets in this assemblage allow us to infer that the knappers were highly skilled at maintaining cores effective for the production of formal blades and at coping appropriately with errors. The knappers working at concentration Sb-9 in the Kamishirataki 2 site relied more on highly developed fine-motor skill than those of the Hattoridai 2 and Kamishirataki 8 sites, in order to produce formal and long blades from large chunks of obsidian debris. With regard to identifying the technical skill level involved, four of the refitted sets in this assemblage appear to be the result of knapping activity carried out at an identical skill level. Probably novices did not knap within or near concentration Sb-9 at the Kamishirataki 2 site.

It is of interest to note that many of the blades detached from the blade cores in this assemblage were abandoned at concentration Sb-9, while some of the blade cores were exported from the site. In these cases, every stage in the course of the manufacturing process was performed with the utmost precision, but almost all of the products were left on the spot, unlike at the Hattoridai 2 and the Kamishirataki 8 sites. One conclusion that can be drawn from this is that the expert knappers were not aiming at producing good blades for immediate use, but rather instructing beginners. These materials can be interpreted as "academic cores" (Johansen and Stapert 2008): cores worked by an expert knapper in what seems to have been a pedagogic demonstration for the benefit of a beginner knapper. A similar situation was also confirmed for refitted artifacts from the Pincevent site (Bodu et al. 1990). The refitted sets from concentration Sb-9 at the Kamishirataki 2 site suggest that novices had the opportunity to observe operational sequences performed by experts and to gather complex knowledge concerning the repertoire of gestures as well as advanced know-how.

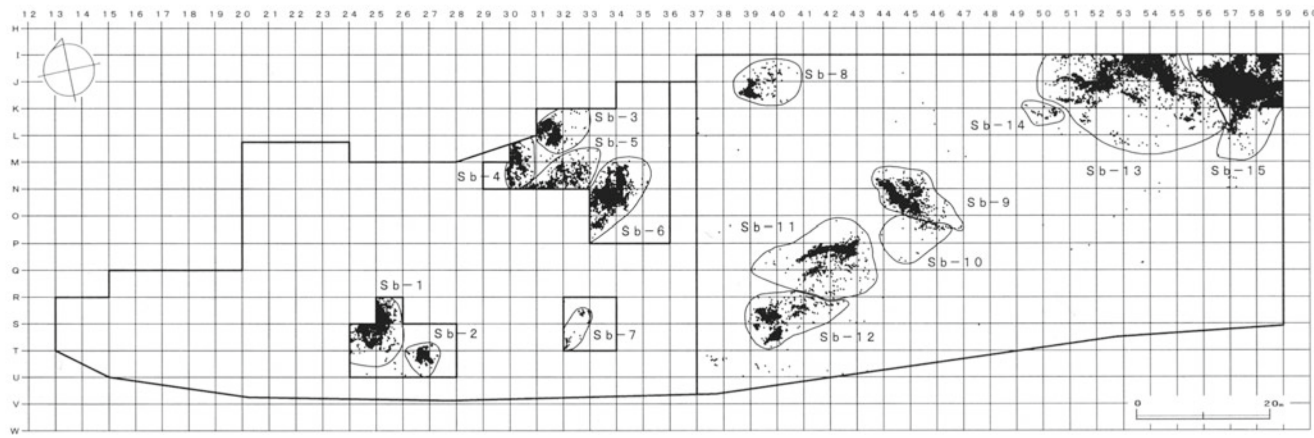


Fig. 9.14 Distributions of stone artifacts in the Kamishirataki 2 site (Naganuma et al. 2001)

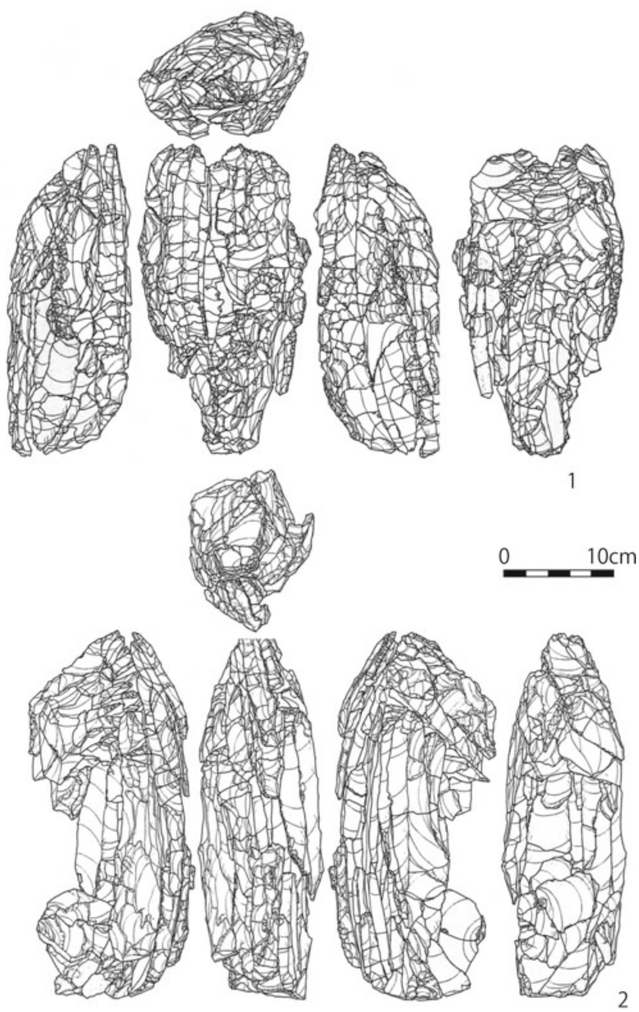


Fig. 9.15 Refitted sets from the Kamishirataki 2 site (1) (Naganuma et al. 2001). *1*: No. 142, *2*: No. 136

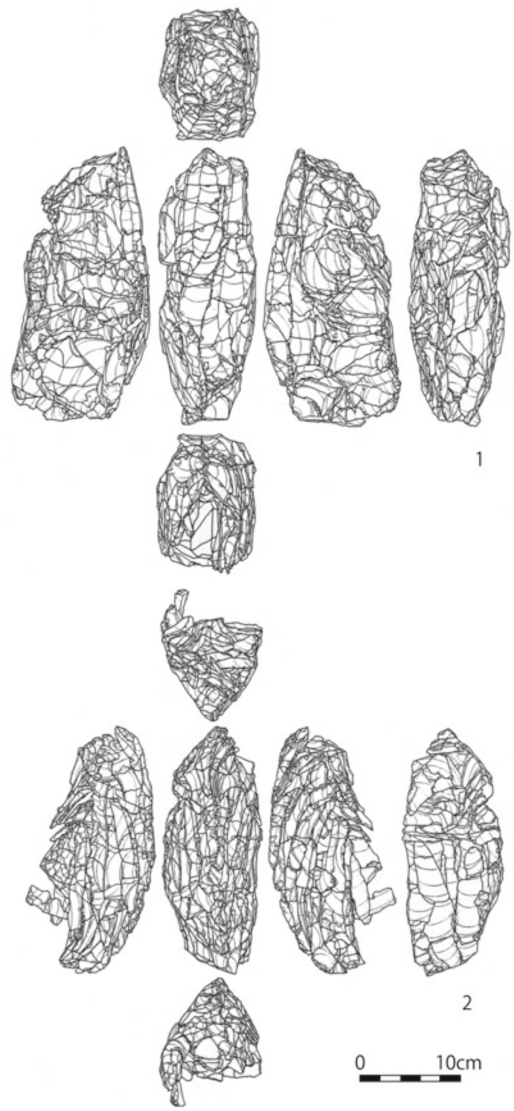


Fig. 9.16 Refitted sets from the Kamishirataki 2 site (2) (Naganuma et al. 2001). *1*: No. 137, *2*: No. 124

Table 9.3 Refitted sets from concentration Sb-9 at the Kamishirataki 2 site

No.	Raw material	Size (cm)	Weight (g)	Blade core	Number of recovered blades	Total number of refitted pieces
142	Angular gravel	37×16×18	5,212	Absent	40	422
136	Angular gravel	34×12×15	2,298	Absent	25	195
137	Angular gravel	28×10×14	2,231	Absent	14	278
124	Angular gravel	25×10×12	1,283	Present	34	217

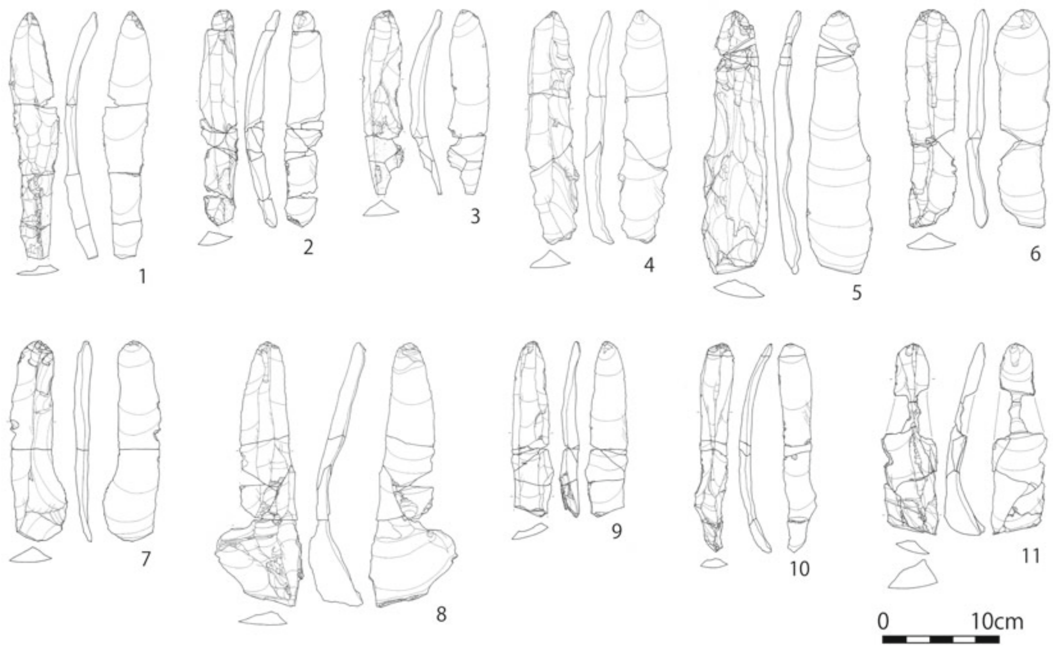


Fig. 9.17 Blades from the Kamishirataki 2 site (Naganuma et al. 2001). *1–4*: No. 142, *5–8*: No. 136, *9*: No. 137, 10–*11*: No. 124

9.5 Discussion and Conclusions

This paper presents an analysis of the lithic refitted artifacts from the Upper Paleolithic assemblages at the Shirataki sites and highlights some questions as to how we can obtain information regarding knappers' skill levels in the past from an analysis of lithic refitted artifacts. As a result, I can reveal more variation than might have been previously expected both in the expressions of skill among the lithic refitted artifacts and in the evidence for training/learning processes at the Upper Paleolithic sites.

Previous studies of the learning and skill transmission process of prehistoric lithic technologies, particularly in Europe, have argued that differences in knappers' competence at lithic manufacture can be identified based on the technological characteristics of the refitted artifacts. In such studies, the spatial distributions of the refitted sets at the sites have been also analyzed to examine the place of knapping activities and the relationships between multiple knappers with different levels of skill. In this paper, I have focused on the relationship between the technological characteristics generally interpreted as skill signatures in previous studies and on the variety of raw materials, especially their size and form, in order to reconsider the hypothesis that the selection of raw material itself depended on differences in the knappers' technical skill levels.

Comparison of the lithic refitted artifacts from the Shirataki sites reveals that the particular choice of raw material "packages" is not always associated with different skill levels among knappers. In particular, the materials from concentration Sb-90 at the Kamishirataki 8 site suggest that the highly skilled knappers would occasionally use different forms of obsidian pebbles for blade production. This is different from what has been observed in the Magdalenian lithic assemblages in the Paris Basin (Audouze and Cattin 2011; Pigeot 1990, 2010). Perhaps, such difference may be related to the raw material condition at Shirataki where abundant and various obsidian raw materials could be procured nearby the sites. Anyway, it is apparent that we archaeologists need to reexamine the hypothesis that the selection of raw material itself is always conditioned by differences in technical skill levels among knappers.

As mentioned above, there are only minor differences in size between the angular and round cobbles in the refitted sets from concentration Sb-90 at the Kamishirataki 8 site. Furthermore, I have shown that the knappers involved in the formation of this assemblage had equivalent skills in blade production. Therefore, in this case the variety of shapes in the lithic raw materials did not significantly influence the formation of technological variability usually related to the expression of skill. This subsequently leads to my conclusion that the reduction sequence using the round obsidian cobbles recovered from concentration Sb-23–31 at the Hattoridai 2 site can be understood as the result of knapping episodes by novices, and not as a simplified reduction by expert knappers due to the influence of morphological features of the raw materials, because the situation relative to lithic raw materials is the same among the Shirataki sites.

To shed light on the relationship between the lithic raw materials and the technological characteristics of reduction sequences, we should instead focus on the difference in size and quality of the raw materials. In other cases it may be difficult to distinguish the results of novice knapping from some of the simplified reductions performed by experts due to the use of small and/or lower quality "packages" of raw material (e.g., Audouze and Cattin 2011; Shea 2006), given that the situation relative to raw material is not the same.

The results of analysis presented in this paper suggest that the missing blade cores ("ghost cores") as well as the missing blades ("ghost blades") among the refitted sets can offer a useful signature of the knappers' skill. In particular, that there are missing blades in the refitted sets is of more important for such an assessment because this factor is apparently correlated to the technological characteristics that reflect distinctions in the knappers' skill at the Hattoridai 2 and Kamishirataki 8 sites. Among the highly mobile foragers at these sites, who possessed blades as tools and blanks, blades were frequently exported from the localities of lithic production near raw material sources when good results were achieved technically. Thus the "ghosts" of blades may represent the results of knapping activities performed by experts. Whenever it is difficult to distinguish the results of novice knapping from the simplified reductions performed by experts, as noted above, an assessment of the "ghosts" of blades in the refitted sets might provide reliable and specific information concerning the skill levels of knappers.

Furthermore, I have drawn some conclusions concerning the skill learning process employed at the Shirataki sites for lithic production. The results of present analysis provide an impressive case study of skill learning behaviors in the production of obsidian blades. Data from the lithic refitted artifacts from concentration Sb-23–31 at the Hattoridai 2 site shows that novice knappers carried out simple training exercises at this site, sometimes also observing the performance of skilled knappers at an adjacent spot. The analysis revealed that the activity zones of the skilled knappers and novice knappers were clearly separated. It is reasonable to suppose this was based on well-defined spatial rules. This spatial segregation gives us an important clue as to the place at which knapping episodes by novices occurred at this site. Such spatial patterning demonstrates that knapping episodes by novices did not co-occur with that by experts. The differentiated activity zones, inferred through analysis of the Hattoridai 2 site, suggest that both groups of knappers probably paid attention to the other's knapping activities, either explicitly or implicitly. The novices may have been expected to learn by watching the work of experts and then imitating it by themselves. A similar learning process was also confirmed by Grimm (2000).

Ethnographic studies of learning in "small scale societies" have stressed that learning through observation and imitation played an essential role in transmitting knowledge and know-how with regard to craft activities and subsistence from adults to children or adolescents (e.g., Gaskins and Paradise 2010; Hayden and Cannon 1984). The results of analysis from the Hattoridai 2 site may confirm the significance of skill learning through observation and imitation in the context of a prehistoric site.

In contrast, the refitted sets from the Kamishirataki 2 site show that pedagogical demonstrations for the benefit of novices might have been performed there by expert knappers in a more formal context. It is important to note that the expert knappers in this case were not aiming at producing good blades for immediate use, but rather at instructing novices. This case suggests a kind of "teaching" of skill through reduction of "academic cores", although it remains unclear whether or not this was associated with verbal instruction. This is in contrast to ethnographically based claims that this kind of formalized training/learning process is rare among "small scale societies", and in particular forager societies. Such a hypothesis for the refitted sets from the Kamishirataki 2 site may reinforce a necessity of different interpretations for making sense of skill learning process in forager societies, if it occurred not only through careful observation of the operational sequence used by experts and imitation of it, but also through mutual cooperation and a kind of "teaching" of beginners by experts' demonstrations.

According to Hayden and Cannon (1984) and Bamforth and Finlay (2008), self-taught activities, including a degree of trial and error, tend either to be those that are not related to craft production or those that rely more on coarse-motor skills than on highly developed fine-motor skills. As I have suggested here, it is evident that a highly developed level of fine-motor skill was needed for successful blade production at the concentration Sb-9 in the Kamishirataki 2 site, and this perhaps might have resulted in the characterization of the training/learning process at the site. Furthermore, it is important that the training/learning process through a kind of "teaching" of skill was also recognized in the Magdalenian site of France (Bodu et al. 1990). This encourages us to suppose that such process was not a restrictive phenomenon which might have been only seen in the Upper Paleolithic site of Hokkaido, Northern Japan. It brings focus to reconsider a role of some kind of "teaching" involving instruction in the skill transmission process for the highly developed craft production in prehistoric contexts. Of course, definitive conclusions are not easy to draw but the apprenticeship process of prehistoric lithic knappers is far more complex than was previously supposed.

Looking at the results of the refitted artifacts from the Shirataki sites, it is significant that these skill learning behaviors occurred at sites in which the obsidian cobbles favored for use as lithic raw material could be easily and abundantly acquired. Working through trial and error, novice knappers would have likely created vast quantities of debitage (Shea 2006). The availability of raw materials probably permitted such a degree of trial and error by novice knappers or pedagogic demonstration by expert knappers. Therefore, we can conclude that novices were present in camps used for the procurement of obsidian raw materials and the production of blanks and tools. This encourages us to look for traces of children and adolescents in these hunter-gatherer camps at Shirataki. This in turn may eventually provide critical insights into the local group organization composed of men, women, and children, as well as the settlement pattern of prehistoric hunter-gatherers during the late Upper Paleolithic.

Acknowledgements The results discussed in this paper would not have been possible without the support of the Hokkaido Archaeological Operations Center. I would like to thank the organizer of the RNMH 2012 international conference in Tokyo, Takeru Akazawa who gives me an opportunity to contribute this volume. Also, I would like to thank Yoshihiro Nishiaki, Hiroto Nakata, Hiroyuki Suzuki, Yasuo Naoe, Yuichi Nakazawa and two anonymous reviewers for their comment and help. Of course, all errors and omissions are solely my responsibility. My research presented in this paper was supported by MEXT KAKENHI Grant Number 23101501.

References

Abe A (2003) Kyusekki jidai no ginousa to gijutsu denshou: Niigata-ken Arakawa-dai iseki no sekijin gihou o rei toshite (Difference of skill and technological transmission in Paleolithic: a case study of blade technique at the Arakawadai site, Niigata). Housei Koukogaku (Housei Archaeol) 30:19–44 (In Japanese)

Abe A (2004) Saisekijin seisann gijutsu no ginousa (Difference in skills to produce micro-blades). Housei Shigaku (J Housei Historical Soc Hosei Univ) 61:32–54 (In Japanese)

Abe A (2009) Iseki keisei niokeru kodomo no yakuwari (A role of children in site formation process). In: The Society of Archaeology in Niigata Prefecture (ed) Niigata-ken no Koukogaku (Archaeology in Niigata Prefecture). The Society of Archaeology in Niigata Prefecture, Niigata, pp 1–22 (In Japanese)

Andrews B (2003) Measuring prehistoric craftsman skill: contemplating its application to Mesoamerican core-blade research. In: Hirth KG (ed) Mesoamerican lithic technology: experimentation and interpretation. University of Utah Press, Salt Lake City, pp 208–219

Audouze F, Cattin M (2011) Flint wealth versus scarcity: consequences for Magdalenian apprenticeship. Lithic Technol 36:109–126

Audouze F, Valentin B (2010) A paleohistorical approach to Upper Paleolithic structural changes. In: Bolender DJ (ed) Eventful archaeologies: new approaches to social transformation in the archaeological record. State University of New York Press, Albany, pp 29–47

Bamforth DB, Finlay N (2008) Introduction: archaeological approaches to lithic production skill and craft learning. J Archaeol Method Theory 15:1–27

Bleed P (2002) Obviously sequential, but continuous or stages?: refits and cognition in three late Paleolithic assemblages from Japan. J Anthropol Archaeol 21:329–343

Bleed P (2008) Skill matters. J Archaeol Method Theory 15:154–166

Bodu P, Karlin C, Ploux S (1990) Who's who?: the Magdalenian flintknappers. In: Cziesla E, Eickhoff S, Arts N, Winter D (eds) Big puzzle: international symposium on refitting stone artefacts. Holos, Bonn, pp 143–164

Clark JE (2003) Craftsmanship and craft specialization. In: Hirth KG (ed) Mesoamerican lithic technology: experimentation and interpretation. University of Utah Press, Salt Lake City, pp 220–233

Dobres M-A (1995) Gender and prehistoric technology: on the social agency of technical strategies. World Archaeol 27:25–49

Dobres M-A, Hoffman C (1994) Social agency and the dynamics of prehistoric technology. J Archaeol Method Theory 1:211–258

Eren MI, Bradley B, Sampson CG (2011) Middle Paleolithic skill-level and the individual knapper: an experiment. Am Antiquity 76:229–251

Ferguson JR (2008) The when, where, and how of novices in craft production. J Archaeol Method Theory 15:51–67

Finlay N (1997) Kid-knapping: the missing children in lithic analysis. In: Moore J, Scott E (eds) Invisible people and processes. Leicester University Press, Leicester, pp 203–212

Finlay N (2008) Blank concerns: issues of skill and consistency in the replication of Scottish Later Mesolithic blades. J Archaeol Method Theory 15:68–90

Finlay N (2011) Skill and the substance of stone: exploring issues of raw material diversity in Scottish Arran pitchstone. Lithic Technol 36:189–200

Gaskins S, Paradise R (2010) Learning through observation in daily life. In: Lancy DF, Bock J, Gaskins S (eds) The anthropology of learning in childhood. AltaMira, Walnut Creek, pp 85–118

Geribàs N, Mosquera M, Vergès JM (2010) What novice knappers have to learn to become expert stone toolmakers. J Archaeol Sci 37:2857–2870

Grimm L (2000) Apprentice flintkanpping: relating material culture and social practice in the Upper Paleolithic. In: Derevenski JS (ed) Children and material culture. Routledge, London, New York, pp 53–71

Hayden B, Cannon A (1984) Interaction inference in archaeology and learning frameworks of the Maya. J Anthropol Archaeol 3:325–367

Högberg A (2008) Playing with flint: tracing a child's imitation of adult work in a lithic assemblage. J Archaeol Method Theory 15:112–131

Inizan M-L (2012) Pressure débitage in the old world: forerunners, researchers, geopolitics-handling on the baton. In: Desrosiers PM (ed) The emergence of pressure blade making: from origin to modern experimentation. Springer, New York, pp 11–42

Inizan M-L, Lechevallier M, Plumet P (1992) A technological marker of the penetration into North America: pressure micoblade debitage. Its origin in the Paleolithic of North Asia and its diffusion. In: Vandiver PB, Druzik JR, Wheeler GS, Freestone IC (eds) Issues in art and archaeology III. Materials research society symposium proceedings, vol 267. Materials Research Society, Pittsburgh, pp 661–681

Janny F (2010) Technologie lithique à Verberie: production domestique et apprentissage. In: Zubrow E, Audouze F, Enloe JG (eds) The Magdalenian household: unraveling domesticity. State University of New York Press, Albany, pp 51–75

Johansen L, Stapert D (2008) Stone age kids and their stones. In: Sørensen M, Desrosiers PM (eds) Technology and archaeology: proceedings of the SILA workshop, vol 14. The National Museum Studies in Archaeology and History, Copenhagen, pp 5–39

Karlin C, Julien M (1994) Prehistoric technology: a cognitive science? In: Renfrew C, Zubrow EB (eds) The ancient mind: elements of cognitive archaeology. Cambridge University Press, Cambridge, pp 152–164

Karlin C, Ploux S, Bodu P, Pigeot N (1993) Some socio-economic aspects of hunters-gatherers in the Paris Basin. In: Berthelet A, Chavaillon J (eds) The use of tools by human and non-human primates. Clarendon, Oxford, pp 318–337

Kimura H (1992) Reexamination of the Yubetsu technique and Study of the Horokazawa Toma lithic culture. Archaeological Museum of Sapporo University, Sapporo

Minar JC, Crown PL (2001) Learning and craft production: an introduction. J Anthropol Res 57:369–380

Mitsuishi N (2009) Yubetsu gihou sekkigun niokeru hakuri no jiko to sono hyouka (A case study about the accidents occurred in removal process of the Yubetsu method: from observation on the refitted artifacts in Onbara 1 microblade industry). In: Inade T (ed) Onbara 1 Iseki (The Onbara 1 Prehistoric site). Onbara Sites Archaeological Investigations Team, Okayama, pp 336–344 (In Japanese)

Morrow TM (1996) Lithic refitting and archaeological site formation processes: a case study from the Twin Ditch site, Greene County, Illinois. In: Odell GH (ed) Stone tools: theoretical insights into human prehistory. Plenum, New York, London, pp 345–376

Naganuma T, Sakamoto H, Suzuki H, Naoe Y (2000) Shirataki Isekigun I (The Shirataki sites, vol I). The Hokkaido Archaeological Operations Center, Ebetsu (In Japanese)

Naganuma T, Suzuki H, Naoe Y (2001) Shirataki Isekigun II (The Shirataki sites, vol II). The Hokkaido Archaeological Operations Center, Ebetsu (In Japanese)

Nakazawa Y, Izuho M, Takakura J, Yamada S (2005) Toward an understanding of technological variability in microblade assemblages in Hokkaido, Japan. Asian Persp 44:276–292

Naoe Y (2003) Hokkaido Shirataki I iseki ni mirareru sekki zukuri no gijyutsusa (A difference of skill in the lithic technology among the Shirataki I site, Hokkaido). Koukogaku Jarnaru (Archaeol J) 504:20–24 (In Japanese)

Naoe Y (2007) Shirataki Isekigun VII (The Shirataki sites, vol VII). The Hokkaido Archaeological Operations Center, Ebetsu (In Japanese)

Naoe Y (2012) Shirataki Isekigun XII (The Shirataki sites, vol XII). The Hokkaido Archaeological Operations Center, Ebetsu (In Japanese)

Olive M (1988) Une habitation Magdalénienne d'Etiolles: L'Unité P15, vol 2, Mémoires de la Société Préhistorique Française 20. SPF, Paris

Pelegrin J (1990) Prehistoric lithic technology: some aspects of research. Archaeol Rev Cam 9:126–141

Pelegrin J, Karlin C, Bodu P (1988) Chaîne opératoires: un outil pour le préhistorien. In: Tixier J (ed) Technologie préhistorique (Notes at Monographies Techniques du CRA, No. 25). Editions du CNRS, Paris, pp 55–62

Perdaen Y, Noens G (2011) The social organization of technology: an early Mesolithic case study from the low countries. Lithic Technol 36:165–176

Pigeot N (1987) Magdalénienne d'Etiolles. Economie de débitage et organisation sociale. XXVe Suppl. Gallia Préhistoire. CNRS Editions, Paris

Pigeot N (1990) Technical and social actors: flintknapping specialists at Magdalenian Etiolles. Archaeol Rev Cam 9:126–141

Pigeot N (2004) Les derniers Magdaléniens d'Etiolles: perspectives culturelles et paléohistoriques. XXXVIIe Suppl. Gallia Préhistoire. CNRS Editions, Paris

Pigeot N (2010) Éléments d'une organisation sociale Magdalénienne à Étiolles du savoire-faire au statut social des personnes. In: Zubrow E, Audouze F, Enloe JG (eds) The Magdalenian household: unraveling domesticity. State University of New York Press, Albany, NY, pp 198–212

Roux V, Brill B, Dietrich G (1995) Skill and learning difficulties involved in stone knapping: the case of stone-bead knapping in Khambhat, India. World Archaeol 27:63–87

Shea JJ (2006) Child's play: reflections on the invisibility of children in the Paleolithic record. Evol Anthropol 15:212–216

Shelley PH (1990) Variation in lithic assemblages: an experiment. J Field Archaeol 17:187–193

Soressi M, Geneste J-M (2011) The history and efficacy of the chaîne opératoire approach to lithic analysis: studying techniques to reveal past societies in an evolutionary perspective. PaleoAnthropol 2011:334–350

Sternke F (2011) Struck between a rock and hard place: skill transmission and differential raw material use in Mesolithic Ireland. Lithic Technol 36:221–236

Stout D (2002) Skill and cognition in stone tool production. Curr Anthropol 43:693–772

Suzuki H (2007) Gensanchi iseki niokeru iseki kan heni kenkyu: Hokkaido Engaru-cho Shirataki isekigun chutsudo no kogata funazoko gata sekki sekkigun wo taishou toshite (A study on the inter-site variability among the sites nearby the source of lithic raw material: an example from the assemblages with small boat shaped tools in the Shirataki sites, Engaru, Hokkaido). In: The Department of Archaeology, the Graduated School of Letters at Tohoku University (ed) Koukogaku Dansou (Papers of Archaeology). Rokuichi Shobou, Tokyo, pp 109–130

Suzuki H, Naoe Y (2006) Shirataki Isekigun VI (The Shirataki sites, vol VI). The Hokkaido Archaeological Operations Center, Ebetsu (In Japanese)

Takahashi S (2001) Suichouen iseki no gijutsu to kouzou (Technology and structure of the Suichouen site). In: Takano M, Takahashi S (eds) Suichouen Iseki Hakkutsu Chousa Houkokusho (A report of the archaeological research at the Suichouen site). The Board of Education in Habikino City, Habikino, pp 192–221 (In Japanese)

Takakura J (2010) Refitted material and consideration of lithic reduction sequence among the microblade assemblages: a view from the Okushirataki-1 site, Hokkaido, Northern Japan. Asian Persp 49:332–347

Takakura J (2012) Emergence and development of the pressure microblade production: a view from the Upper Paleolithic of Northern Japan. In: Desrosiers PM (ed) The emergence of pressure blade making: from origin to modern experimentation. Springer, New York, pp 285–306

Valentin B, Julien M, Bodu P (2002) Lithic raw material economy in the Late Glacial of the Paris Basin: case studies from the Magdalenian, Federmesser and long blade technology. In: Fisher LE, Eriksen BV (eds) Lithic raw material economies in the Late Glacial and early Postglacial Europe, vol 1093, BAR International Series. BAR, Oxford, pp 117–132

Yoshizaki M (1961) Shirataki isekigun to Hokkaido no mudoki bunka (The Shirataki sites and the preceramic culture in Hokkaido). Minzokugaku Kenkyu (Jpn J Ethnol) 26:13–23 (In Japanese)

“Gifting” As a Means of Cultural Transmission: The Archaeological Implications of Bow-and-Arrow Technology in Papua New Guinea

10

Yoshihiro Nishiaki

Abstract

This paper examines the learning processes related to bow-and-arrow technology in a hunter-gatherer community in Papua New Guinea in an attempt to help illuminate prehistoric learning behaviors. The data analyzed have been derived from Hitoshi Watanabe’s ethnographic research conducted in 1971, which left a corpus of remarkably rich information on the learning processes relating to the manufacture and use of bows and arrows. The present study revealed that the giving of bows and arrows played a vital role in the transmission of bow-and-arrow technology in the society under study. Emphasizing the significance of giving, this paper proposes a “gift-education model,” which can help create an explanatory framework for learning processes in prehistory. The model has its strengths in archaeology because I believe that “gifting” may have left material evidence that is testable through archaeological records. If the presence of gifts can be used as a proxy for investigating prehistoric learning, it can open a new dimension for research into prehistoric learning.

Keywords

Bows and arrows • Gift • Hunter-gatherer society • Marcel Mauss • Teaching-learning system

10.1 Introduction

An important objective of the *RNMH* research project is to investigate the processes in the *Replacement of Neanderthals by Modern Humans* from the viewpoint of possible differences in the learning behaviors (and abilities) of these two hominid populations. Archaeological evidence is the most important in this project, as it provides us with virtually exclusive material evidence of past learning behaviors. Evidence evaluated since 2010 includes a combination of material remains recovered from archaeological sites and data obtained through both experimental archaeology and ethno-archaeology (Nishiaki 2012). In this paper, I will refer to the ethno-archaeological approach in order to explore how observations of modern human society can help illuminate prehistoric learning behaviors.

The data analyzed in this paper are, in part, those originally collected by Hitoshi Watanabe (1919–1998) at the hamlet of Wonie, West Papua New Guinea in 1971 (Watanabe 1975; Nishiaki 2011). Based on the data analysis with reference to prehistoric learning, I present a model of the learning processes of bow-and-arrow technology in this society and address their implications for interpreting the Paleolithic material records, particularly for Neanderthals and modern humans.

10.2 Ethno-Archaeological Approach to Prehistoric Learning

Analogies based on contemporary evidence are indispensable for reconstructing past behaviors (e.g., Binford 1983; David and Kramer 2001), especially for learning behaviors in the Paleolithic period, which rarely leave indisputable

Y. Nishiaki (✉)
The University Museum, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
e-mail: nishiaki@um.u-tokyo.ac.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_10, © Springer Japan 2013

material remains that directly help in reconstructing the behaviors themselves. Exceptionally well-preserved Paleolithic sites may yield some such evidence (e.g., Pigeot 1990, 2010; Grimm 2001; van Peer et al. 2010; Audouze and Marie-Isabelle 2011; see Chap. 9). However, ethnographic knowledge from contemporary society no doubt contributes to a better understanding of the learning processes that took place there. Because of the increasing interest during the past few decades in exploring individuals and social systems that have left archaeological records (Dobres 2000; Gamble and Porr 2005), attempts to define the learning processes or strategies of craft technology have become popular. A number of prominent examples are in pottery manufacturing (e.g., Hayden and Cannon 1984; Wallart 2008; Köhler 2012).

On the other hand, comparable ethno-archaeological approaches to stone tool manufacturing, which would be more beneficial for Paleolithic records, are evidently few. The rarity undoubtedly reflects the difficulty of finding societies that maintain this technology today (cf., White 1969; Hayden 1979). Rare examples include investigations of modern bead makers in India (Bril et al. 2005), hide workers in Ethiopia (Gallagher 1977; Weedman 2005), and axe makers at Irian Javan (Stout 2002, 2005). All of these efforts have certainly yielded insightful results on the learning strategies of lithic technology. Yet, we should be cautious in evaluating the results from those investigations because the evidence they discuss was obtained in significantly different contexts from that surrounding stone tool manufacture in the Paleolithic period. First, the current ethno-archaeological research into stone tool manufacturing deals with specialized technologies for producing commercial or trade goods. The assumption is that specialized technology is transmitted through limited communities in a given society with, for example, an apprenticeship arrangement. Such a system, however, is unlikely to have been in place among Neanderthals and early modern humans; rather, lithic manufacturing was more likely a skill shared by at least all the males of any Paleolithic society. Second, the research examples enumerated above investigate only a limited range of stone tool manufacturing technologies. They do not show cases of making hunting tools, such as spears and arrowheads. These lithic artifacts are the most frequently used to define prehistoric lithic industries or cultures because of their frequent stylistic changes, which are thought to reflect the serious concerns of prehistoric hunters. Modeling the learning process of hunting tool manufacture would provide the most appropriate framework for making analogies regarding the lithic tradition.

Thus, this paper examines the learning processes of bow-and-arrow technology in a hunter-gatherer community in Papua New Guinea. The bows and arrows are made of bamboo, wood, or iron, rather than stone, and the presence of bows and arrows in the Paleolithic period has not been conclusively demonstrated. Nevertheless, the overall context—that is, the fact that they are hunting tools manufactured by all the male members of the society—suggest their suitability for the present purpose. Moreover, considering the rapid disappearance of our research opportunities into traditional tool manufacturing technologies in hunter-gatherer societies, I believe that the data collected by Watanabe's comprehensive research in 1971 (Watanabe 1975) is worthy of reanalysis in the new context.

10.3 Watanabe's Bow-and-Arrow Census Data from Papua New Guinea

Watanabe's fieldwork was carried out in the native village of Wonie in western Papua New Guinea in July and August 1971 (Fig. 10.1). The village consisted of 16 households/families, with a population of 19 married males, 26 married females, and 58 unmarried individuals including infants. The primary forms of subsistence were hunting and gathering/farming (with men doing the hunting and women the gathering/farming). The farming was conducted on a limited scale, confined to cultivation of taro and yamo near the houses. This village was chosen for intensive ethnographic research because of the absence of a school and church, which suggested less acculturation from Western civilization may have been present at that time (Watanabe 1975, pp. 7–8). Although children went to school at a neighboring town and one male (government councilor) possessed a gun, the community itself relied upon a traditional hunter-gatherer way of life.

The uniqueness of Watanabe's research lies in its methodology, which he called the "bow-and-arrow census." He collected "census" data on the population and on the bows and arrows present in the village. The census data contain comprehensive information on sex, age, education, occupation, family, experience of hunting, etc., whereas the data on the bows and arrows include raw material, measurements, manufacturer, owner, and so on. This unique corpus of data provides us with a rare opportunity to compare the skills of bow-and-arrow manufacturing and the use of this technology by age groups, and the results can be used to deduce the learning processes involved in this society. Most of the census data are presented in Watanabe's monograph (1975), and additional data can be obtained from the Hitoshi Watanabe collection that was donated to the University Museum, Tokyo, after his death (Nishiaki 2007, 2011). The latter collection includes original specimens, such as arrows and bows (Fig. 10.2), manufacturing tools, and toy bows and arrows, along with videotapes, photos, and numerous written records.

10.3.1 Bow-and-Arrow Data

During Watanabe's research, the village contained 28 bows and 110 arrows. The arrows consisted of numerous types that were categorized by the natives according to differences in use,

Fig. 10.1 Location of Wonie in Papua New Guinea

Fig. 10.2 A selection of bows and arrows collected by Hitoshi Watanabe at Wonie in Papua New Guinea

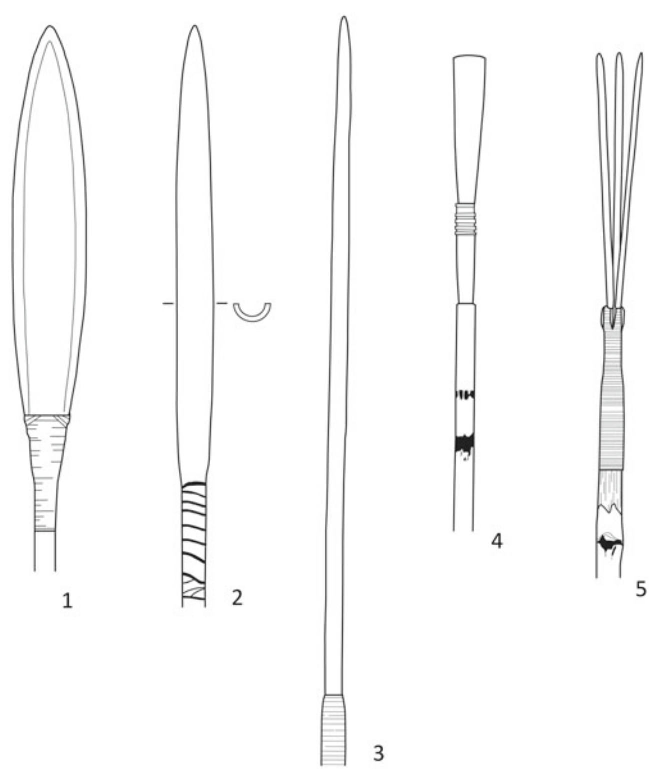


Fig. 10.3 Fundamental arrow types in Wonie. *1*: *Giri Sung* (Watanabe 1975: Fig. 5-a), *2*: *Sung* (Watanabe 1975: Fig. 3-d), *3*: *Gnalib* (Watanabe 1975: Fig. 15-A2), *4*: *Dupa* (Watanabe 1975: Fig. 15-C2), and *5*: *Waya* (Watanabe 1975: Fig. 6-a)

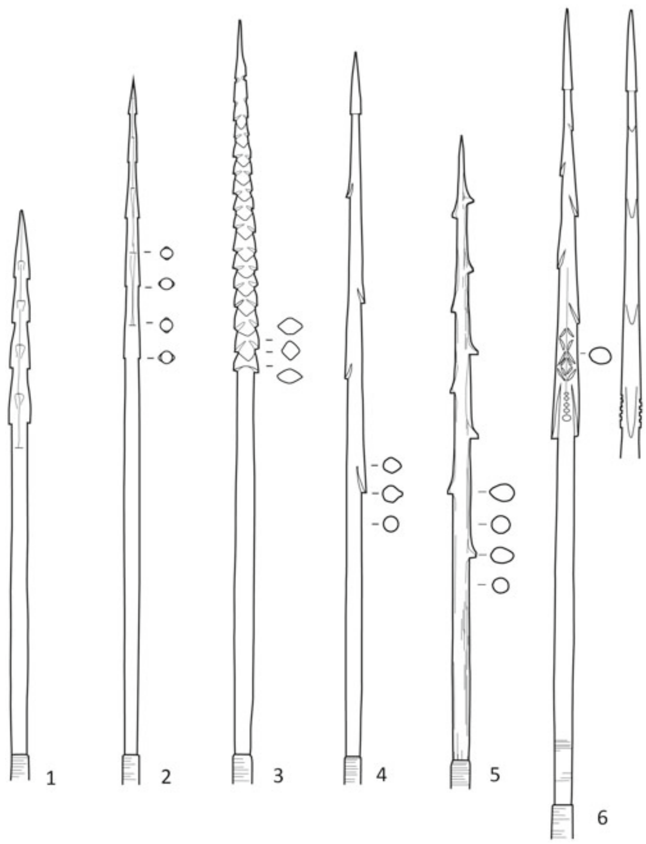


Fig. 10.4 Examples of variations of *gnalib* arrow types in Wonie. *1*, *2*: *Mer, 3*: *Kurumi, 4*, *5*: *Arukop,* and *6*: *Kioruoru* (after Watanabe 1975: Fig. 9)

raw material, form, and style. The principal types were *sung* for hunting large mammals, *gnalib* for middle and small animals, *dupa* for birds, and *waya* for fish. *Sung* arrows, traditionally made of bamboo and wood, were called *giri sung* when made of iron (Fig. 10.3). These types were further divided by the shape of the tips, barbs, decoration, and so on (Fig. 10.4). The local hunters thus distinguished more than 30 types of arrows. On the other hand, bows were not divided into many types. Thus, arrows appeared to have been a greater concern in the native typology of the hunters of Wonie.

10.3.2 Population Data

The personal information that Watanabe collected included name, family, school experience, and other miscellaneous information for all the inhabitants. The age was recorded only according to the native system: *Bogasobjog* (the youngest), *Yambuga*, *Kewalbuga*, *Rugalog*, and *Meed* (Watanabe 1975, pp. 8–9). Both *Bogasobjog* and *Yambuga* denote "small boys," distinguishable only by whether or not they are capable of fluent speech. *Kewalbuga* represents "single boys," which changes to *Rugalog* when they marry. The *Meed* is defined as adult males with gray hair. Precise information on age was obtained only from a limited number of the younger generation, who had school experience. It shows that all of the *Bogasobjog* were between zero and five years old, *Yambuga* were between six and 15 years old, and *Kewalbuga* were between 16 and 21. Accordingly, *Bogasobjog*, *Yambuga*, *Kewalbuga*, *Rugalog*, and *Meed* may be compared to infants, children, adolescents, adults, and elderly, respectively. However, we should remember that these age grades do not necessarily correspond to the life stages as defined in modern health science (cf., Yamauchi and Hagino 2014).

10.4 Manufacture and Use of Bows and Arrows

My research goal is to establish a model based on the learning process for bow-and-arrow technology in this community. This model should incorporate information on how an individual learns to make and use the bow and arrow during his lifetime and how that knowledge is transmitted from one generation to the next. For this purpose, the data on bows and arrows are analyzed in relation to the age order of their manufacturers and owners. Particular attention will be paid to the ownership of each bow and arrow, as Watanabe (1975) emphasizes the solid tradition of giving bows and arrows in Wonie society. Here, differences in bow-and-arrow types in terms of their manufacture and use are examined according to the age grades previously identified (i.e., *Bogasobjog*, *Yambuga*, *Kewalbuga*, *Rugalog*, and *Meed*).

10.4.1 Possession

First, Watanabe examined the possessors of bows and arrows, demonstrating that they were possessed only by males at Wonie. Therefore, bow-and-arrow technology was a gender-biased technology in this society, transmitted among the males only. Figure 10.5 shows the possession rates by age grades. It is noteworthy that half of even the infants (*Bogasobjog*), who were not capable of fluent speech and had never participated in hunting, already possessed bows and arrows (Fig. 10.6: left). The possession rate increases by age grade, reaching nearly 100% for the *Kewalbuga* and *Rugalog* grades. Then it drops for the elderly group, *Meed*. One of the two males who belonged to this age grade had already retired from hunting. The high possession rates among the *Kewalbuga* and *Rugalog* obviously reflected the Wonie males' principal occupation: hunting. The *Rugalog* without bows and arrows included a government councilor, who did not hunt on a regular basis.

Males of different age grades possessed different types of bows and arrows. Whereas differences are seen in the morphological and stylistic types (see below), the most remarkable difference is in the size (Figs. 10.6 and 10.7). Both the bows and arrows of the *Bogasobjog* are significantly smaller than those

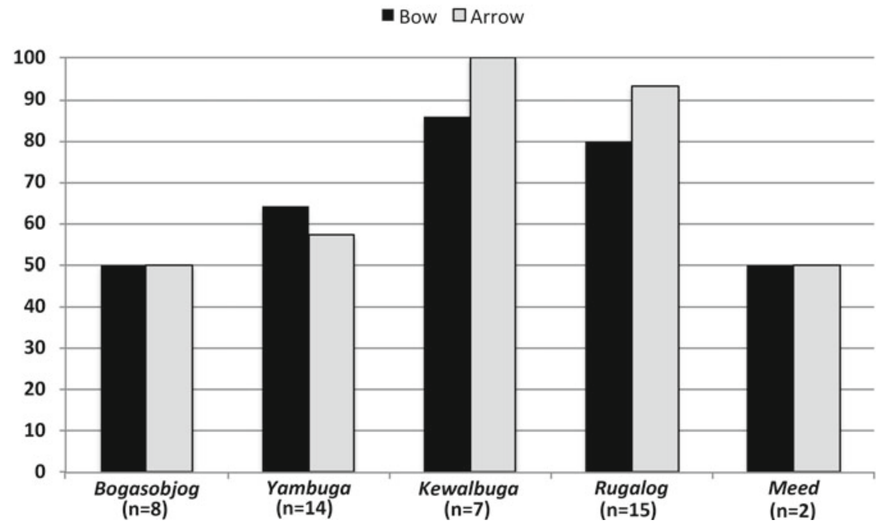


Fig. 10.5 Frequencies of individuals who possess bows and arrows in Wonie by age grade

Fig. 10.6 Males in Wonie possessing bows and arrows. *Bogasobjog, Yambuga*, and *Kewalbuga* (from left)

of the *Kewalbuga*, *Rugalog*, and *Meed,* all of which are about the same size, with sizes for the *Yambuga* falling between them. This pattern is undoubtedly related to the growth of the possessors. The larger variation of the size for the *Yambuga* group, which included boys between 6 and 15 years old at this village, probably reflects the adolescent growth spurt that occurs during those ages (cf., Yamauchi and Hagino 2014).

10.4.2 Manufacturing

The high possession rate of bows and arrows does not mean that every male of this community necessarily made the bows and arrows himself, as it was customary for males to present bows and arrows to one another as gifts. Figure 10.8 compares the proportions of self-made and given bows and arrows by age grades. We should note that none of the bows belonging to the younger generations (*Bogasobjog* and *Yambuga*) were self-made but rather were gifts. The majority of the *Kewalbuga* and all of the *Meed* bows were also gifted. Only in the *Rugalog* stage did almost everyone possess self-made bows. The youngest one possessing a self-made bow was already 21 years old (Watanabe 1975, p. 56).

The patterns for arrows (Fig. 10.8: right) resemble those for bows, with notable differences in the *Yambuga*. About half of the *Yambuga* possessed self-made arrows, although

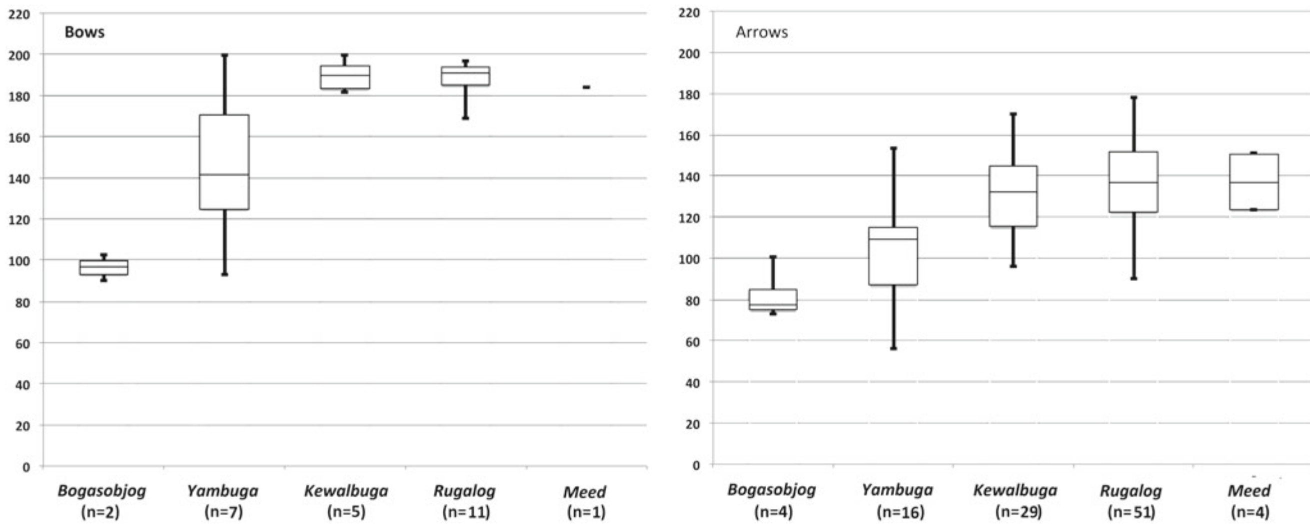


Fig. 10.7 Lengths of bows and arrows in Wonie by age grade

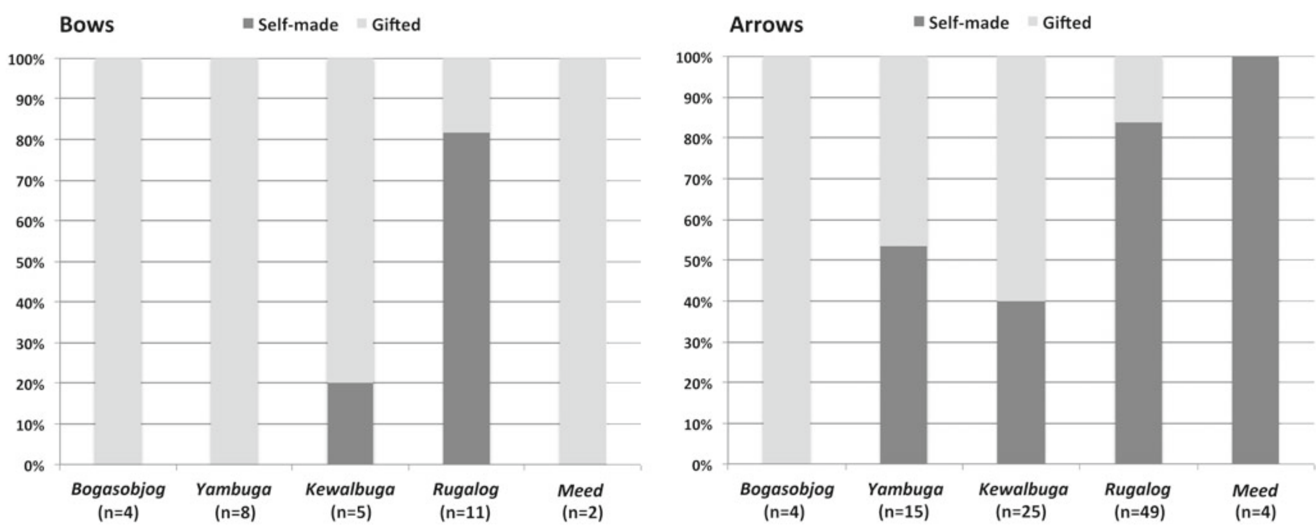


Fig. 10.8 Frequencies of self-made and gifted bows and arrows in Wonie by age grade

they had no self-made bows. The youngest one with a self-made arrow was 14 years old, compared to the 21-year-old male who was the youngest with a self-made bow. This difference suggests that boys began manufacturing arrows earlier in their life history than they did bows. Likewise the *Meed*, who no longer made bows themselves, still possessed self-made arrows.

10.4.3 Skill Improvement

No quantitative data are available from Watanabe's records that detail the improvement process of the bow-and-arrow manufacturing skill. However, his detailed descriptions of the tool kit possessed by John, a 14-year-old boy, are useful for inference (Watanabe 1975, pp. 47–50). John was the youngest male to possess self-made arrows. His bow was a gift from Waiba, John's father's younger brother's son and a *Rugalog* of unknown age. John had two self-made and one given arrows (Fig. 10.9). The self-made arrows were a *dupa* and a *waya* (Fig. 10.9: 2, 3), which were specifically used for birds and fish, respectively. His low skill in arrow manufacturing was manifest particularly in the hafted parts: the shaft is split, the bondage rough. The poor workmanship is even more evident when compared with the *giri sung* arrow (Fig. 10.9: 3), a gift from his 18-year-old brother-in-law, Sokoli. In this case, we may assume that the arrow-making skill improves sometime between 14 and 18 years of age, a period corresponding to middle-to-late adolescence. It is obvious that a quantitative analysis using a large sample

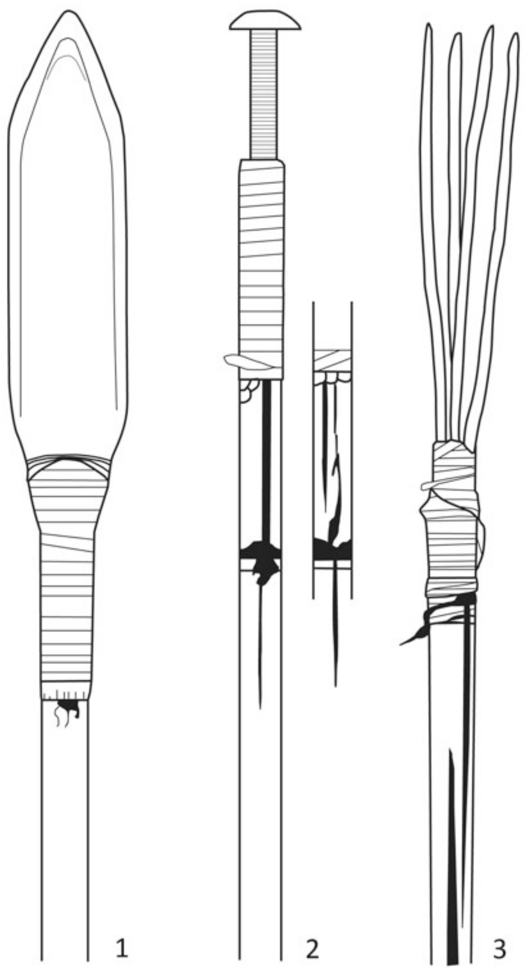


Fig. 10.9 John's arrow set (Watanabe 1975: Fig. 14B1–3)

size would be required to confirm this estimate. Variability among individuals should also have existed.

10.4.4 Using

The major game hunted at Wonie consisted of cassowaries, wild pigs, wallabies, bandicoots, birds, and fish. Watanabe (1975, pp. 71–72) interviewed a total of ten *Yambuga* and *Kewalbuga* (from 10 to 21 years old) to ask what game animals they had ever hunted (Table 10.1). Their answers indicated evident changes in game animlas according to age. Roughly three stages can be defined (Table 10.1): *Yambuga*—small animals (fish, bird, bandicoot, and wallaby), early *Kewalbuga*—medium-sized animals (+ wild pig), and late *Kewalbuga*—large animals (+ cassowary). The game hunted by even younger boys, if any, was not investigated, though according to the above pattern, it probably would have consisted of mainly fish and birds. This inference is based on the fact that infants and young children spent plenty of time with their mothers (see Plate 1: 3, 4 in Watanabe 1975), so they likely had opportunities to get fish and birds easily when they would go with their mothers to the river to get water.

The differences in game animals by age grade correspond to the changes in the hunters' bows and arrows as well. As noted above (Fig. 10.7), at the stage of *Kewalbuga,* males start using fully developed bows and arrows, which are big enough to kill large animals. All the data indicate that changes in the hunter's body size, bow-and-arrow size, and game animals are closely correlated to each other.

10.5 Transmission of the Bow-and-Arrow Technology

Next, we will analyze the learning processes of bow-and-arrow manufacturing. Watanabe's records say nothing about the teaching of arrow making in Wonie society, but he does refer to some teaching incidents from bow making at school (Watanabe 1975, p. 59). Watanabe was told that pupils in the first grade were taught how to make toy bows, and those in sixth grade were taught how to make small bows for children. However, no one in that age group in the village possessed a self-made bow when Watanabe did his interviews. The bows made at school had been either "burnt away near the school," or given to younger boys. Watanabe (1975, p. 59) inspected the latter bows and noted their inferior workmanship. Thus, I infer that learning bow making at school was novel to the society and that it did not work very well in terms of allowing the pupils to develop their skill fully. As mentioned earlier, the reality is that all of the males possessing self-made bows were older than 20, a long time after graduation from primary school.

What, then, was the traditional strategy for learning bow-and-arrow technology? The actual situation might have been comparable to that often emphasized in hunter-gatherer societies in general: education is carried out without formal teaching, including such means as observations, emulation, pedagogy, trial and error, and so on (Chap. 8). More specifically, I wish to posit that "giving" or "gifting" played a major role in the teaching in Wonie society. The grounds for this hypothesis include the fact that boys began to use bows and arrows earlier than they began to manufacture them, a situation made possible only because the older males would give bows and arrows to younger ones. The younger boys apparently familiarized themselves with bows and arrows using the gifted ones and then began making comparable bows and arrows when they were mature enough. In order to explore this hypothesis, I examine the relationships between the giving and manufacturing of bows and arrows in more detail. For arrows, a sufficient sample size was available, so this case is presented below.

Table 10.1 Relationship of age to experience of killing animals with bow and arrow (data from Table 28 in Watanabe 1975)

		Game animals					
Age grade	Age	Fish	Bird	Bandicoot	Wallaby	Wild pig	Cassowary
Yambuga	10	+	?	?	+		
	10	+	+	+	+		
	14	+	+	+	+		
	14	+		+			
	15 (16?)	+					
Kewalbuga	16	+	+	+	+	+	+
	17	+	+	+	+	+	+
	17	+	+	+	+	+	
	18	+	+	+	+	+	
	21	+	+	+	+		

Table 10.2 Comparison of self-made and gifted arrow types by age group (data compiled from Tables 14–17 in Watanabe 1975)

		Bugasobjog		*Yambuga*		*Kewalbuga*		*Rugajog*		*Meed*	
	Arrow types	Self	Gift	Self	Gift	Self	Gift	Self	Gift	Self	Gift
Toy	Sago leaf		1		3						
Fundamental	*Dupa*		2	4		2		3	1		
	Waya		1	1	1	1		8			
	Gnalib			2	1		2	3			
	Sung						2	2	2		
	Giri sung				3	6	1	17	5	2	
Non-fundamental	*Tau (num)*					1					
	Mer							2		1	
	Mer rubi						1	2			
	Kurumi								1		
	Sebakera rubi						1				
	Bawor							1			
	Tu-pole						1				
	Womemop						1				
	Pako						1				
	Arukop									1	
	Kioruoru						1				
	Rubi						1				
	Kurumi rubi							1			
	Bomwo rubi						1				
	Karako							1			
	Tunip							1			

10.5.1 Relationship Between Giving and Manufacturing

The relationships between given and self-made arrow types by age grades are illustrated in Tables 10.2 and 10.3. I mentioned earlier that there are five fundamental arrow types: *sung, giri sung, gnalib, waya* and *dupa*, each of which has subtypes defined by variations in shape, barbs, and decoration. Table 10.2 shows the distribution of the morphological types of arrows among different age grades. The arrows possessed by *Bogasobjog* were limited to *dupa* and *waya* gifted from elders. In the next age grade, *Yambuga*, arrows of these types were mostly manufactured by themselves, and the types of gifted arrows changed into new types, including *giri sung* and *gnalib*. The *Kewalbuga* manufactured *giri sung* arrows themselves. It is notable that the males of this age group possessed a remarkably diversified range of non-fundamental types of arrows and that all these arrows, except for one piece of *tau,* were gifts. The arrow types possessed by the *Rugalog* similarly showed a large variability, but differing from the *Kewalbuga,* in which most of the non-fundamental arrows were self-made. The trend of self-manufactured arrows continued in the elderly group, the *Meed*.

Table 10.3 Comparison of self-made and gifted arrow decoration types by age group (data compiled from Table 13 in Watanabe 1975)

		Bugasobjog		*Yambuga*		*Kewalbuga*		*Rugajog*		*Meed*	
Decoration types		Self	Gift	Self	Gift	Self	Gift	Self	Gift	Self	Gift
Simple	N		1	2	4	1		6		4	
	A2 & N & N		2	3	1	3	1	13	7		
	A1 & N & N		1				2	7	1		
	N & A-b & N			1							
	N & B & N							1			
	N & N & B-e					2	1		1		
	N & N & B-b					1	1				
Complicated	A2 & N & B-e				3		1	3			
	A1 & N & B-e			2		2	2	3			
	A1 & N & B-c/e						1				
	N & A-a & A-b/B-d-1					1	1				
	N & A-a & A-b						2				
	A1 & N & B-d-3							2			
	A1 & A-a-1 & N							1			
	A2 & A-a-2 & N							1			
	N & A-a-2/A-b/B & B-d-2							1			
	A2 & A-b & B-e							1			
	A1 & A-a & A-b/B-c						1				
	A1 & A-a-2/A-b/B & B-d-2							1			
	A1 & A-b & B-e							1			

The relationship shown in Table 10.2 can be summarized as follows: arrows were first gifted, then self-made according to the order of age grade. At the same time, we can observe a trend of changes from possessing fundamental to non-fundamental types. It is my supposition that the gifts may have guided the younger generation to determine what they wanted to manufacture when they became mature enough.

Almost the same diachronic pattern is recognizable for the decoration types of arrows (Table 10.3). The decoration types of Wonie arrows can be classified by a combination of types of scraping, design, and color (Watanabe 1975, pp. 35–42). In Table 10.3, each decoration type is designated by a combination of these three features. For the sake of convenience, I group them here into simple and complicated ones. Simple arrows have no (N) or only one of the three kinds of decoration. Complicated arrows are those that retain at least two elements—scraping, design, or color. For example, *kioruoru* (Fig. 10.4: 6) is classified as a complicated type because it exhibits all the traces of scraping (A1), the use of red smearing pigment (A-a), and geometric patterns (A-b/B-c).

The changing pattern shown in Table 10.3 resembles that noted for the morphological types. The arrows possessed by the *Bogasobjog,* which were all gifts, are very simple, dominated by those without (N) and with simple decorations (A1 or A2). Then, arrows with slightly more complicated decorations (A2&N&B-e) began to be given in the *Yambuga* stage, while arrows with simple decorations were self-made. A great change occurs in the next age grade, *Kewalbuga*. Diversified and far more complicated decoration types were gifted, and in the next age grade, *Rugalog,* most of the diversified arrows were of self-manufacture. No complicated arrows were given to them at that age, but all of them were self-made. Here again, the diachronic pattern—gift first, then self-manufacture, and simple first, then complicated—is maintained. This trend ends in the *Meed*. No one gave arrows to the elderly, and all the arrows possessed by the *Meed* were non-decorated and self-made.

10.5.2 Relationship Between Donors and Recipients

Watanabe's data include information about the relationship between donors and recipients of arrows. Figure 10.10 is a summary of the data by age grades. The patterns for bows and arrows are similar to each other. First, most of the donors were kin to the recipients. Second, giving from fathers to their sons was most popular, especially among the young recipients. The donors for the *Bogasobjog* were always their fathers. Fathers were similarly the most common donors for the *Yambuga*, but donors to the latter included elder brothers, as well as uncles and cousins in the case of bows. Third, donors who were friends rather than kin to the recipients appeared in the *Kewalbuga,* with friends becoming the most common donors in the next age group, the *Rugalog*. For the *Meed*, all the arrows were self-made while all the bows were gifts from their sons.

10.6 The Learning Processes of Bow-and-Arrow Technology at Wonie

I have presented the results of my analysis of Watanabe's data wherein I examined the changing patterns in skill with and knowledge of bow-and-arrow technology by age. It should be noted that Watanabe was able to document information about the bows, arrows, and inhabitants merely as a snapshot in the summer of 1971. Therefore, precisely speaking, the data presented above never showed the changes that actually occurred. Nevertheless, an analysis according to age grade yields intriguing results that strongly suggest the presence of changes in the manufacturing/using and giving/learning of bows and arrows in the life history of the inhabitants.

Figure 10.11 presents a summary of the revealed patterns. I would like to suggest three important features as characteristics of the learning system in the Wonie society. First, learning bow-and-arrow technology was domain-specific and appeared to progress cumulatively. The knowledge and skill of the manufacture and use of this technology, as well as the decorative style, did not develop simultaneously. For example, *Bogasobjog* used the bow and arrow only during play or hunting that was insignificant for subsistence, while *Yambuga* used them for capturing small animals, such as birds and fish. The *Yambuga* began to make their own arrows and the *Kewalbuga* to manufacture their own bows. The manufacture improved in the *Kewalbuga* stage, and by the early *Rugalog* age, all of the essential elements involved in bow-and-arrow manufacture, use, and decoration were established. The necessary skills and knowledge were thus acquired one by one.

Another feature is that learning bow-and-arrow technology may be understood as part of a dynamic system. As in most hunter-gatherer societies, there was no evidence of positive teaching. However, the Wonie case suggests that their tradition of giving served as a means of teaching. In nearly all the cases examined, bows and arrows were given by older individuals to younger ones, with a few exceptions among the adolescent and adult groups, who exchanged products with one another. Younger individuals were given bows and arrows specific to their age groups. When they were older, they manufactured the same types of bows and arrows that they had received early in life and then gave some of these items to the younger boys. The knowledge of bows and arrows thus continued through cycles of giving (Fig. 10.11); hence, giving may be considered the driving force of this system.

Third, it is also important that the present study offers an insight into the learning schedule in the Wonie society. A learning schedule refers to changes in learning strategies in an individual's life history (Aoki et al. 2012). The learning strategies are generally divided into social learning and individual learning. Social learning denotes learning from somebody else, whereas individual learning is accomplished by the learners themselves through trial and error. In addition, social learning can be further divided according to the teacher-learner relationships, which include vertical, oblique, and horizontal social learning. Most people know that in human society, learning begins with social learning from parents (vertical), which is combined with individual learning in the later stages of life (Aoki et al. 2012; Hewlett et al. 2011).

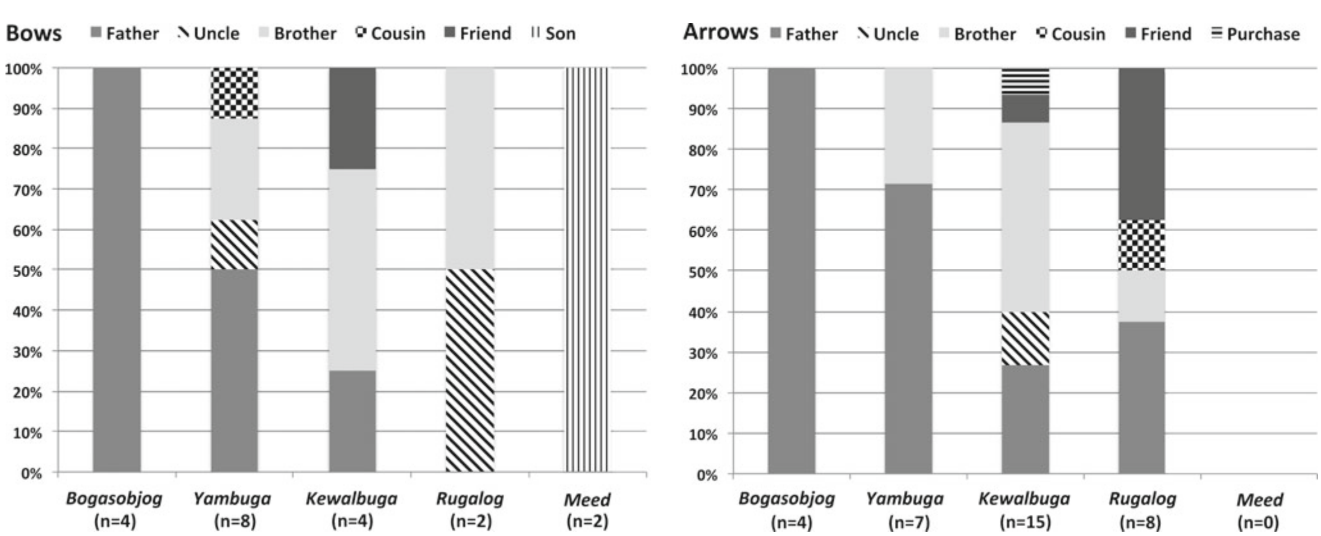


Fig. 10.10 Frequencies of the donors of bows and arrows in Wonie by age grade

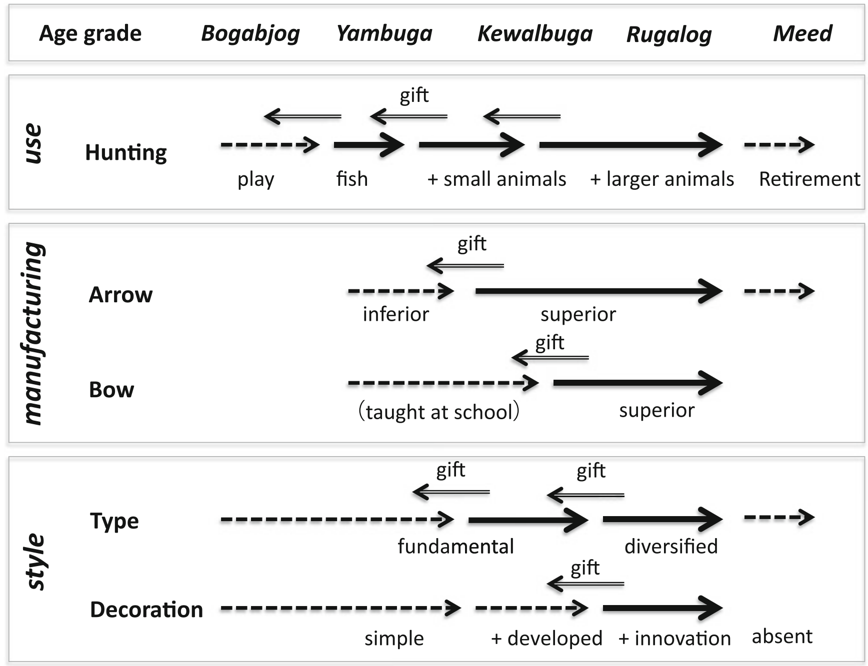


Fig. 10.11 Learning processes of bow-and-arrow technology in Wonie in relation to the development

In the Wonie context, the available data do not refer to the teacher-learner relationships but rather to donor-recipient relationships. Yet, the idea that giving functions as a means of teaching could substitute for teacher-learner relationships. As shown in Fig. 10.10, the relationships characteristic of each age grade are as follows:

Bogasobjog: vertical gift (social learning)
Yambuga: vertical + oblique gift (social learning)
Kewalbuga: vertical + oblique + horizontal gift (social learning)
Rugalog: horizontal gift (social learning) + self-making (individual learning)
Meed: self-making (individual learning)

When a gift is regarded as social learning and self-making of new arrow types as individual learning, the changing patterns by age at Wonie closely resemble the learning schedules surmised from theoretical biology (Aoki et al. 2012) and actually reported from field work among modern hunter-gatherers (Hewlett et al. 2011; also see Chap. 11). Vertical transmission dominates in the earlier age groups, with oblique and horizontal transmissions occurring next. Finally, individual learning becomes popular in adulthood (*Rugalog*). This striking coincidence reinforces our notion of giving as a means of cultural transmission.

10.7 Implications for Paleolithic Archaeology

Learning is an essential behavior for generating and maintaining culture. Investigations into the evidence of the learning behaviors of the Paleolithic period must serve as an important source of information for understanding how a variety of cultures were generated and maintained from an evolutionary perspective (e.g., Finlay 1997; Shea 2006; Tehrani and Riede 2008). Indeed, a certain amount of research has been accumulated (Grimm 2001; Pigeot 1990, 2010). Research examples include tantalizing investigations of knapping areas for novice and skilled knappers, and even suggest their interactions, such as emulation and teaching (Chap. 9). However, these examples are related to the Upper Paleolithic and later sites, and comparable data on the earlier periods has been limited (e.g., van Peer et al. 2010; Hovers et al. 2011; Stapert 2007), although the current *RNMH* project very much needs the latter. Continuous efforts to look for evidence of learning among the Neanderthal society are needed for comparison with the learning behavior of modern humans.

The present study suggests a couple of directions for future attempts to explore differences in the learning behaviors between Neanderthals and modern humans, and their consequences to the archaeological record.

The first is the role of gifting in the past learning-teaching system. I have emphasized its importance or at least its very close correlation with cultural transmission. In addition, plenty of archaeological evidence for giving exists at modern human sites—for example, in the form of trade or exchanged objects. However, was there any evidence of giving among Neanderthal societies? Giving foods and other natural resources to younger generations has no doubt existed since much earlier times, but whether or not an established tradition existed of giving or exchanging artifacts remains uncertain. One piece of positive evidence is the common occurrence of Middle Paleolithic stone tools that exhibit traces of reutilization. One quantitative analysis at a

Levantine Mousterian site showed the proportion of stone artifacts with double-patination to be as high as 10% of all the cores and retouched tools (Nishiaki 1985, p. 216). This finding demonstrates that recycling of artifacts abandoned earlier was a popular habit among Neanderthal societies. If so, the use of artifacts made by contemporary others, such as gifts, would also have been common, although lithic artifacts intentionally given to somebody in the Middle Paleolithic periods are difficult to identify. On the other hand, counter evidence can be set forth. The absence of grave goods at the burials, or at least doubts about their existence, and long distance trade goods, as often represented by obsidian and shells at Upper Paleolithic sites, may shed doubt on the presence of a steady giving tradition. Indeed, as suggested by Pettitt (2011, pp. 129–130), the lack of convincing examples of grave goods points to the idea that artifacts or objects did not play a social role but rather an immediate economic role. Under this circumstance, a tradition of gifting would not have been developed. Given the powerful effect of giving in both vertical and horizontal cultural transmission, this issue is worthy of more investigation in the future. Supposing that the tradition of giving artifacts was, if not absent, at least limited in scale, the learning of material culture in Neanderthal society likely differed significantly from that of the Upper Paleolithic man as well as from that of modern hunter-gatherers, such as the Wonie of Papua New Guinea.

The second implication of the present study concerns the learning schedule. Some of the archaeological literature argues that ways of cultural transmission relate to rates of cultural evolution. Employing a model proposed by Cavalli-Sforza and Feldman (1981) who suggest different rates of cultural evolution caused by different modes of transmission, such as vertical and horizontal social learning, attempts have been made to explain the long persistence of prehistoric lithic traditions (MacDonald 1998; Lycett and Gowlett 2008; also see Mithen 1996). For instance, Lycett and Gowlett (2008) suggest that a "many-to-one" system could have operated as the dominant mode among the Acheulean populations. In that system, which represents a combination of vertical and oblique transmissions, younger members learn from the elder members of the group, which includes not only parents but also other individuals. However, we should be reminded that learning strategies can easily change within the life-history of an individual. The current models of cultural transmission employed in the archaeological literature seem too simplistic.

Theoretical considerations (Aoki et al. 2012), ethnographic data (Hewlett et al. 2011), and the present study all suggest that, in modern human society, social learning is popular in the earlier life history, and individual learning becomes most evident only in adulthood and afterward. This pattern draws attention to the significance of the life history of the Paleolithic hominids in interpreting their learning behaviors. Was the life history of the Neanderthals the same as that of modern humans? Although much remains to be debated, current evidence tends to suggest a shorter childhood and a shorter life itself for the Neanderthals (e.g., Hawcroft and Dennell 2001; Smith et al. 2010; also see Nowell and White 2010). Given the importance of childhood for social learning and adulthood for individual learning, differences in the life history would directly affect the learning strategies and, hence, the outcome of learning as well.

One more implication may be pointed out relating to the life history. This paper shows that the learning system of Wonie was domain-specific. The manufacturing skill for bows and arrows was developed only during adolescence, while actual use of a bow and arrow starts much earlier. This delayed start in self-manufacturing is understandable because of the complicated knowledge, physical power, and skill required for making bows and arrows, especially their shafts (Watanabe 1975). The delayed start for learning manufacturing is also consistent with the nature of bow-and-arrow technology. It is a gender-specific, male technology, which is acquired after a boy is mature enough. If the circumstances are more or less applicable to prehistoric society, one might expect different learning processes in lithic technology, which is dependent on the different functions of stone tools, such as butchering and hunting tools. A life history model may provide a hint for interpreting the considerable developments and diversification of the hunting tools of the Upper Paleolithic, in comparison with the rather limited variability in the Middle Paleolithic.

10.8 Conclusion

Watanabe (1975) noted the importance of giving or gifting in cultural, sociological, and ecological terms. In this paper, I emphasize its importance in the teaching-learning system of a human society. Giving seems to have played a primary role in the transmission of bow-and-arrow technology in Wonie society. While the motive behind giving was not specified in Watanabe's records, there was no obvious reciprocation between the giver and recipient. The scenario is probably comparable to what Mauss (1990/1922) described as primitive society's giving tradition in the early twentieth century. The elders made gifts of bows and arrows to younger individuals, who then reciprocated when they became older. Likewise, gifts were also made to other individuals in the same generation as the adolescents afterwards, and reciprocation between the giver and the recipient was accomplished through exchange. This system cycled throughout the generations.

The gift-education model seems to deserve testing in both ethnographic and archaeological terms. If tested by ethnographic data, it can help make an explanatory framework for learning-teaching behaviors in a society without a habit of positive teaching. The model also has its strengths in archaeology because giving may leave material evidence that is testable through archaeological records. If the presence of gifts can be used as a proxy for investigating prehistoric learning, it can open a new dimension for research into prehistoric learning.

References

Aoki K, Wakano JY, Lehmann L (2012) Evolutionarily stable learning schedules and cumulative culture in discrete generation models. Theor Popul Biol 81:300–330

Audouze F, Marie-Isabelle C (2011) Flint wealth versus scarcity: consequences for Magdalenian apprenticeship. Lithic Technol 36:109–126

Binford L (1983) In pursuit of the past. Thames & Hudson, London

Bril B, Roux V, Dietrich G (2005) Stone knapping: Khambhat (India), a unique opportunity? In: Roux V, Bril B (eds) Stone knapping: the necessary conditions for a uniquely hominin Behavior. Macdonald Institute Monograph. Oxford University Press, Oxford, pp 53–71

Cavalli-Sforza LL, Feldman FW (1981) Cultural transmission and evolution: a quantitative approach. Princeton University Press, Princeton

David N, Kramer C (2001) Ethnoarchaeology in action. University of Cambridge, Cambridge

Dobres M-A (2000) Technology and social agency: outlining a practice framework for archaeology. Blackwell, Oxford

Finlay N (1997) Kid knapping: the missing children in lithic analysis. In: Moore J, Scott E (eds) Invisible people and processes: writing gender and childhood into European archaeology. Leicester University Press, New York, pp 201–212

Gallagher P (1977) Contemporary stone tools in Ethiopia: implications for archaeology. J Field Archeol 4:407–414

Gamble C, Porr M (2005) The hominid individual context: archaeological investigations of Lower and Middle Palaeolithic landscapes, locales and artefacts. Routledge, London

Grimm L (2001) Apprentice flintknapping: relating material culture and social practice in the Upper Palaeolithic. In: Derevenski JS (ed) Children and material culture. Routledge, London, pp 53–71

Hawcroft J, Dennell R (2001) Neanderthal cognitive life history and its implications for material culture. In: Derevenski JS (ed) Children and material culture. Routledge, London, pp 89–99

Hayden B (1979) Palaeolithic reflections: lithic technology and ethnographic excavation among Australian aborigines. Humanities, Englewood Cliffs

Hayden B, Cannon A (1984) Interaction inference in archaeology and learning frameworks of the Maya. J Anthropol Archaeol 3:325–367

Hewlett BS, Fouts HN, Boyette AH, Hewlett BL (2011) Social learning among Congo Basin hunter–gatherers. Phil Trans R Soc B 366:1168–1178

Hovers E, Malin Sky-Buller A, Goder-Goldberger M, Ekshtain R (2011) Capturing a moment: identifying short-lived activity locations in Amud Cave, Israel. In: Le Tensorer J-M, Jagher R, Otte M (eds) The Lower and Middle Palaeolithic in the Middle East and neighbouring regions, vol 126, Etudes et Recherches Archéologiques de l'Université de Liège (ERAUL). Université de Liège, Liège, pp 101–114

Köhler I (2012) Learning and children's work in a pottery-making environment in northern Côte d'Ivoire. In: Spittler G, Bourdillon MFC (eds) African children at work: working and learning in growing up for life. Lit Verlag, Wien, pp 113–145

Lycett SJ, Gowlett JJ (2008) On questions surrounding the Acheulean 'tradition'. World Archaeol 40(3):295–313

MacDonald DH (1998) Subsistence, sex, and cultural transmission in Folsom culture. J Anthropol Archaeol 17:217–239

Mauss M (1990/1922) The gift: forms and functions of exchange in archaic societies. Routledge, London

Mithen S (1996) Social learning and cultural tradition: interpreting Early Palaeolithic technology. In: Steele J, Shennan S (eds) The Archaeology of human ancestry: power, sex and tradition. Routledge, London, pp 207–229

Nishiaki Y (1985) Truncated-faceted flakes from Levantine Mousterian assemblages. Bull Dept Archaeol Univ Tokyo 4:215–226

Nishiaki Y (2007) Catalogue of anthropological materials in the Hitoshi Watanabe collection. The University Museum, The University of Tokyo, material reports, vol 68. The University of Tokyo, Tokyo

Nishiaki Y (2011) An ethno-archaeological approach to the study on prehistoric learning. In: Tanabe C (ed) Proceedings of the 4th conference on the replacement of Neanderthals by modern humans. Okazaki Conference Center, Okazaki, pp 44–45

Nishiaki Y (2012) An archaeological study of the learning behaviours of Neanderthals and Modern Humans. RNMH Project Ser 1:32–37

Nowell A, White M (2010) Growing up in the Middle Pleistocene. In: Nowell A, White M (eds) Stone tools and evolution of the human cognition. University Press of Colorado, Boulder, pp 67–81

Pettitt P (2011) The Palaeolithic origins of human burials. Routledge, London

Pigeot N (1990) Technical and social actors: flintknapping specialists at Magdalenian Etiolles. Archaeol Rev Cam 9:126–141

Pigeot N (2010) Elements d'une organization sociale Magdalenienne a Etiolles du savoir-faire au statut social des personnes. In: Zubrow E, Audouze F, Enloe JG (eds) The Magdalenian household: unraveling domesticity. State University of New York Press, Albany, pp 198–212

Shea J (2006) Child's play: reflections on the invisibility of children in the Paleolithic record. Evol Anthropol 15(6):212–216

Smith TM, Tafforeauc P, Reidd DJ, Pouechb J, Lazzari V, Zermenoa JP, Guatelli-Steinbergf D, Olejniczakb AJ, Hoffmang A, Radovcićh J, Makaremii M, Toussaintj M, Stringerk C, Hublinb I-J (2010) Dental evidence for ontogenetic differences between modern humans and Neanderthals. Proc Natl Acad Sci USA 107(49):20923–20928

Stapert D (2007) Neanderthal children and their flints. PalArch's J Northwest Eur 1(2):16–38

Stout D (2002) Skill and cognition in stone tool production: an ethnographic case study from Irian Jaya. Curr Anthropol 43:693–722

Stout D (2005) The social and cultural context of stone-knapping skill acquisition. In: Roux V, Bril B (eds) Stone knapping: the necessary conditions for a uniquely hominin behaviour, MacDonald Institute Monograph. Oxford University Press, Oxford, pp 331–340

Tehrani JJ, Riede F (2008) Towards an archaeology of pedagogy: learning, teaching and the generation of material culture traditions. World Archaeol 40(3):316–331

van Peer P, Vermeersch PM, Paulissen E (2010) Chert quarrying, lithic technology and a modern human burial at the Palaeolithic site of Taramsa 1, Upper Egypt. Leuven University Press, Leuven

Wallart H (2008) The way of the potter's mother: Apprenticeship strategies among Dii potters from Cameroon, West Africa. In: Stark MT, Bowser BJ, Horne L (eds) Cultural transmission and material culture: breaking down boundaries. University of Arizona Press, Tucson, pp 178–198

Watanabe H (1975) Bow and arrow census in a west Papuan lowland community: a field for functional-ecological study. University of Queensland, Anthropological Museum, Occasional Papers in Anthropology, vol 5. University of Queensland, Auckland

Weedman K (2005) Gender and stone tools: an ethnographic study of the Konso and Gamo hideworkers of Southern Ethiopia. In: Frink L, Weedman K (eds) Gender and hide production. Altamira, Lanham, pp 175–196

White JP (1969) Typologies for some prehistoric flaked stone artefacts of the Australian New Guinea highlands. Archaeol Phys Anthropol Oceania 4(1):18–46

Yamauchi T, Hagino I (2014) Estimation of the period of childhood and child growth characteristics of pygmy hunter-gatherers in southeast Cameroon. In: Akazawa T, Ogihara N, Tanabe HC, Terashima H (eds) Dynamics of learning in Neanderthals and modern humans: cognitive and physical perspectives, vol 2. Springer, New York

"*Ekeloko*" The Spirit to Create: Innovation and Social Learning Among Aka Adolescents of the Central African Rainforest

11

Bonnie Hewlett

Abstract

Innovation, as an element of behavioral plasticity, has been hypothesized to enhance the fitness and survivability of individuals, while overall increasing the diversity, and longevity of cultural traits overtime. This study examined innovations and their transmission amongst Aka forager adolescents of central Africa. Developmental studies and evolutionary models predict: older adolescents should be more innovative than children and adults; older adolescent males should be more likely to seek out innovations; innovations should spread by horizontal transmission and; adolescents should pay attention to prestigious ("successful") peers. In-depth and structured interviews, informal observations, video taping, and systematic ranking and sorting techniques with 20 Aka adolescents of Central African Republic and 10 Aka adult individuals, with five identified as being "innovators," were utilized to evaluate existing studies.

Contrary to expectations, creation of innovative technologies adopted by others occurred more frequently by adults than adolescents and, both male and female adolescents sought out new innovations from adults rather than peers. Male adolescents did not seek out innovations from female adults, while female adolescents sought out innovations from both adult males and females. As predicted, adult males were more often listed as innovators than adult females. Adolescents of both sexes were more likely to seek out, and pay for, new behaviors, innovations and new technologies than were adults or children. Both males and females frequently listed being seen as more attractive to the opposite sex as the main reason for acquiring new behaviors and or technologies. Additionally, adolescents listed character qualities of the innovators, which could be described as pro-social, and sought out those individuals who exhibited those qualities as well as those who were "good teachers," utilizing teaching methods which would produce high fidelity cultural transmission of the innovative trait.

Keywords

Adolescence • Africa • Cultural transmission • Hunter–Gatherers • Innovation • Social learning

B. Hewlett (✉)
Department of Anthropology, Washington State University, 14204 NE Salmon Creek Avenue, Vancouver, WA 98686-9600, USA
e-mail: hewlettb@vancouver.wsu.edu

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_11,

11.1 Introduction

Innovation and social learning are often described as responsible for playing significant roles in the evolution of cultural systems with arguments chiefly structured around the transmission and diffusion of novel information, behaviors and or artifacts, the receptivity of a society to inventions and the role of innovation as an adaptive response to highly variable climatic or social conditions, providing solutions to new problems and reducing uncertainty and risk (for definitions of innovation and invention see O'Brien and Shennan 2010, pp. vi–18; Henrich in O'Brien and Shennan 2010, p. 99; Kameda and Nakanishi 2002; Barton et al. 2011). However, not all innovations are in response to environmental adversity and instability, nor developed to meet specific needs (Henrich in O'Brien and Shennan 2010; Diamond 1999, p. 246). Innovative behavior is not unique to humans, and as with social learning, often occurs in a variety of ways and ecologies (Nishida 1987; Galef 1992; Tomasello et al. 1993, in Boesch 1995; Boesch 2003; Kameda and Nakanishi 2002; Laland and Reader in O'Brien and Shennan 2010; pp. 37–52). However, as noted by Thornton and Samson (2012) what motivates particular individuals to innovate, and others to seek out and learn the new behavior, remains inadequately understood.

Studies with nonhuman primates, birds and fish assessing the relation between innovation and competitive abilities have provided some insight into the drive behind innovative behavior. For example, low ranking individuals in some species, (e.g. meerkats, fish, birds and some primates) unable to physically outcompete higher-ranking individuals, show innovative propensities or engage in risk-taking, innovative behavior (Thornton and Samson 2012; Reader and Laland 2001; Reader and Laland 2003; Laland and Reader 1999a, b; Katzir 1982; Biondi et al. 2010; Morand-Ferron et al. 2011; Cole and Quinn 2012). Species such as *Pan troglodytes* (Goodall 1986 in Thornton and Samson 2012) achieve high social rank by a display of innovative behavior.

Human adolescents have species specific social and cognitive abilities, learning and problem solving skills, creativeness, and, transitioning into the reproductive stage of the human life cycle, are prompted to engage in risk taking and exploratory behaviors (especially adolescent males, see MacDonald and Hewlett 1999), reputation building, mate attraction and selection and social network building (Bogin 2013; Ellis 2013; Hewlett et al. 1986; see also Reader and Laland 2001). Adolescents should be quick to imitate or choose to learn from prestigious and innovative peers, and disseminate this knowledge to other adolescents (see Thornton and Samson 2012 and; Henrich 2001 for further discussion of cultural transmission and diffusion of innovation). As expressed by Rogers;

> …most people depend mainly upon a subjective evaluation of an innovation that is conveyed to them from other individuals like themselves who have previously adopted the innovation. This dependence on the experience of near peers suggests that the heart of the diffusion process consists of the modeling and imitation by potential adopters of their network partners who have adopted previously (1995, p. 18)

While adolescents in egalitarian societies, such as the foragers of central Africa, are typically not considered "low ranking individuals," they are highly motivated to pay attention to and learn from successful others. As Henrich argues, "learners ought to be selective in terms of to whom they pay attention for the purposes of cultural learning," preferring those with "greater skill, success, knowledge, health, and prestige" while also "using cues of self-similarity such as gender, size, and ethnicity to help ensure that what they learn is fit for their personal attributes and current or future social roles" (in O'Brien and Shennan 2010, p. 102; see also Chudek et al. 2012 for further discussion of model-biased learning and; Henrich and Gil-White 2001; Henrich et al. 2005 for reviews of the evidence).

While adults certainly innovate, as they possess "an optimum combination of physical fitness, skill, wisdom, and experience" adolescents may be more driven to learn new innovations and/or engage in innovative behavior as they have the most to "gain" in terms of reproductive fitness (Liebenberg 1990, p. 70; Walker et al. 2002). Additionally, this increasing range of adolescent social and sexual exploration, acquisition of complex subsistence skills, and increasing knowledge of the world are taking place at a distinct period of adolescent brain development, a time in which "abstract thought is possible" (Lewis 2008, p. 299). With "some combination" of these "biological changes in brain" and changes in socio-cultural contexts, "new cognitive capacities" including innovative propensities, may arise (Nasir 2005; Tamnes et al. 2010). In the context of increased cognitive abilities, reputation building, lack of subsistence obligations, substantial leisure time, forager values and social structures, and enhanced physical health, forager adolescents may take the lead and invest in exploratory, risk taking, innovative behavior and acquisition and dissemination of new innovations (the "spare time hypothesis" [Kummer and Goodall in Thornton and Samson 2012, p. 1460]). Thus, innovation as a complex cultural and social process may be more likely to occur during adolescence than at other times in the life stage.

This research aims to address the gaps in understandings of individual level of adolescent's perceptions, knowledge and experiences with successful innovations (i.e. those "worthy of attention" [Chudek et al. 2012, p. 47]). More data from small-scale populations in contexts that characterized most of human history are necessary for formulating precise understandings of innovation, what is identified as novel and how this knowledge is socially transmitted and learned. The consequences of environmental and biological changes interacting with culturally driven behavioral changes, innovation, decision making, social learning and cumulative culture, may well have been necessary for the survival of the ancestors of modern humans, and help to explain the replacement of Neanderthals during the Late Pleistocene (Barton et al., 2011, p. 725; see also Henrich in O'Brien and Shennan 2010). The study predicted the following hypothesis based upon developmental and evolutionary theories:

1. Adolescents should be more innovative than children and adults because of developmental increases in cognitive capacity and the potential reproductive value of innovative behavior (Lewis 2008; Nasir 2005; Tamnes et al. 2010).
2. Adolescent males should be more likely to seek out inventions than adolescent females as adolescent males are more likely to engage in risk-taking and exploratory behaviors and more likely to travel greater distances than females (MacDonald and Hewlett 1999; Hewlett et al. 1986; see also Reader and Laland 2001).
3. Innovations should be spread by horizontal transmission, a characteristic form of transmission in adolescence (peer, intergenerational) (Hewlett et al. 2002; Rogers and Jorde 1995).
4. Adolescents should pay attention to prestigious ("successful") peers from whom to learn (Henrich in O'Brien and Shennan 2010, pp. 99–120).

11.2 Methods

This research examines the nature, indigenous understandings, and transmission of innovation among Aka hunter-gatherers. Since little is know about this topic in foragers, the research represented in this paper is primarily inductive and descriptive. Data were collected from in-depth interviews and systematic ranking and sorting techniques with 20 Aka adolescents and 10 Aka adult individuals, approximately 35–40 years of age, five of whom were identified by adolescents as being "innovators." Adolescents were identified by use of indigenous terms designating a particular life stage beginning at around puberty and ending with marriage (12–19 years old). Data included exploration of indigenous concepts and terms of innovation, characteristic features associated with innovations, and free listing of individuals identified as "innovators." Further research incorporated structured interviews detailing how adolescents learned a specific set of 20 skills and tasks (e.g. how to construct a basket, how to make a drum, how they learned a new song/dance); free listing of character qualities of the "innovators"; in-depth interviews with adolescents seeking out new knowledge (e.g. innovative behaviors or inventions) and; in-depth interviews with individuals identified as being innovators.

11.3 Setting and Culturally Constructed Niche of Social Learning

The Aka are one of at least fifteen ethno-linguistic groups of forest foragers, sometimes referred to as "Pygmies," located throughout southwestern Central African Republic (CAR) and the northeastern part of the Republic of Congo (ROC), with an approximate population of 30,000 and population density of less than one person per square mile. They have high fertility (about five to six live births per woman) and high infant and child mortality (approximately 50% for children under age 15) (Hewlett 1992).

Aka live in small intimate camps of 25–35 individuals. The number of people in the camp varies almost daily, as adolescents (and others) travel to other camps or relatives and friends come to visit. Their homes are small, at most 3 m in diameter and 2 m high. Inside the home is a bed of animal skins, leaves, or twigs where the family sleeps together. The *ngondo* (term for adolescent females) huts are smaller and have room enough for one or at most two inhabitants. The bachelor lean-tos, built by the *bokola* (term for adolescent males) are usually larger, rectangular structures, able to house four to six young males. Aka have minimal political hierarchy (a *kombeti*, male elder, is recognized but has very limited authority and no "big men" who hold authority and power over others exist); relatively high gender and intergenerational egalitarianism (no individual is given more respect simply due to their age or gender); and, weak patriclans (*dikandu*) associated with neighboring farmers. Female lines are recognized as well (*mobila*). After an initial one-year period or so of matrilocality when the husband provides brideservice, the Aka are multi-local—moving back and forth between the husband and wife's families.

Aka bands are associated with a village clan and each band has a trail from the village to forest camps. Increasingly, Aka spend less time in forest camps and more time in large camps closer to logging roads, their village farms, schools, and missions. Aka have minimal political hierarchy and "immediate return" values and social organization. Foundational schemas for the Aka include: relatively high intergenerational and gender egalitarianism, values of sharing, flexibility of social roles, respect for the autonomy of individuals, and trust of others.

The social context of learning, such as whom the Aka are close to most of the time, and at what ages and how often they are around innovative "teachers" is important in understanding from *whom* learning occurs, the *way* in which learning occurs, and *what* Aka children are learning. Prior to adolescence, Aka children learn through a variety of mechanisms (e.g., play, dancing, singing, exploration) cultural values, beliefs, and practices within specific and differing social and physical contexts (Hewlett et al. 2011). A good proportion of Aka social learning is early, rapid, and mostly vertical (meaning from parent to child) up to age four to five (Hewlett et al. 2011). A study of Aka cultural transmission (Hewlett and Cavalli-Sforza 1986) demonstrated that most subsistence and social skills were learned by age 10, but mating skills, how to hunt large game, knowledge about special medicine and the supernatural, were acquired during adolescence.

As respect for autonomy is a key foundational schema among the Aka, this leads to self-directed knowledge acquisition. Aka adolescents choose when and what to learn, whom to learn from, and this occurs within a context of continued close physical and emotional contact, an environment where trust and social-emotional security are pervasive (see Hewlett et al. 2011 for a more detailed description of social learning in Aka infants and children). While emotional and physical closeness are such that parents continue to be key facilitators of cultural transmission, adults other than parents also play important roles in adolescents' daily lives, providing the potential for both horizontal (friends and peers) and oblique (other adults) cultural transmission (Hewlett et al. 2011).

11.4 Results

11.4.1 "*Ekeloko*" Innovation: Indigenous Definitions, Processes, and Characteristics

Aka adolescents, and adults as well, described innovation, (*ekeloko*) as the creation of something novel, the "best," something that did not exist in the past, is "new for today." For example, an adolescent male explained that, "(He) has many types of songs and dancing. He does many different, each one is very different. He is wise in his songs, that is how he is different from others." Another adolescent noted that, "N. is a specialist (*njamba*) at making this tom–tom. They look different, are strong and make good music."

Aka terms associated with innovation included:

- *Ekeleko ya inda wa kene* (doing something new)
- *Motou wa ekeleko ya bela* (person who works to create, i.e. works on new)
- *Ekeleko wa mbinda* (create new things) and *Eboko ya elo* (original for today)

Adolescents were very specific in what they saw and described as an innovation; "His baskets are very strong. He goes into forest and gets vine and then he dries it in the sun to make it strong. Other people don't dry the vine in the sun." Examples of innovation processes tended to be what could be termed "modification," enhancement of a trait that exists e.g. a basket or drum made with a new feature or produced in a new way. It is unclear if the production of a new medicine, song or dance could be understood as a process of "modification" or "combination," however, the creation of these new traits were seen by the Aka as innovations (Lewis and Laland 2012).

11.4.2 Characteristics of Innovators

Adolescent salience analysis of freelisting data indicate that kindness, wisdom and quietness were qualities associated with innovative people (see Tables 11.1 and 11.2; summary of quantitative data in Hewlett, in preparation). Males listed kindness and goodness over quietness, and females identified intelligence as the most salient characteristic, followed by wisdom and quietness (Table 11.3). Intelligence had to do with the ability to have good ideas, to be inventive. Kindness and goodness were explained as giving to others, and being concerned with others welfare, respectively. Wisdom was defined

Table 11.1 Composite salience for Aka attributions of innovative people; males and females combined

Attributes	Attributes Σ	Composite salience Σ/n (n = 20)
Kind	5.8	0.29
Quiet	8.61	0.43
Wise	7.08	0.35
Intelligent	3.52	0.18
Good	2.47	0.12
Happy	5.75	0.29
Advisor	5.27	0.26

Table 11.2 Composite salience for Aka attributions of innovative people; males only

Attributes	Attributes Σ	Composite salience Σ/n (n = 10)
Kind	5.53	0.55
Good	4.77	0.47
Quiet	3.41	0.34
Wise	2.13	0.21
Happy	2.69	0.27
Intelligent	0.2	0.02
Advisor	1.47	0.15

Table 11.3 Composite salience for Aka attributions of innovative people; females only

Attributes	Attributes Σ	Composite salience Σ/n (n = 10)
Intelligent	3.75	0.38
Wise	3.67	0.37
Quiet	3.67	0.37
Kind	3.08	0.31
Reflective	1.74	0.17
Creative	1.67	0.17
Hard worker	1.17	0.12

as being one who gives good council and makes good decisions. Being a quiet person was not necessarily being shy or non-talkative, but more generally was used to describe a person who was calm, peaceful, and non-aggressive. An older adolescent girl described innovators in this way, "Creators of new things are older and usually adults. A creative person has good ways of doing something better."

Innovators were described by the adolescents as people who had the "spirit to create," they were "different from others." Aka adolescents often said that the innovators they listed were "good" people who were concerned about others wellbeing. The innovations and personality characteristics of innovators (e.g. wisdom, kindness, quietness and intelligence) could be understood as features of a pro-social individual, all of which are highly valued among the Aka. However, not all innovators could be said to acting altruistically (pro-social), as some would charge a "fee" (e.g. money, necklaces, an ax or pot) for their "knowledge." Adolescents noted that as the innovators "owned" the knowledge and "gave their time to teach," so it was not unexpected that they should be charged. As one adolescent girl explained, "She is the owner of this new basket and paint. The way she makes the basket it is different." The adolescents stated that when they were related to the innovator, the knowledge was generally freely shared, however more detailed and systematic work needs to be conducted to determine if this is consistently the case. Their actions of pro-social behavior, as the Aka innovators themselves suggested, were motivated by altruism and empathy (as well as self-interest), a means to help their families, kin-network and non-kin on other trails.

11.4.3 Innovators Motivations for Teaching Others

Informal interviews with the five innovators revealed that motivations for teaching others generally were altruistic (to help others). As one adult male "innovator" explained, "It gives me pleasure to make people happy. To create it is good. To know many medicines is to help sickness, now I am thinking to create, to find medicine to help heal people." Several "innovators" also mentioned the reward they received by sharing their knowledge, that is the small gifts (e.g. money, axes, pots, or necklaces) that served to aid their families, "If I create something I will be able to get things to take care of this family. I make many new things and people give me things for this knowledge. I give this to my wife to take care of the children."

11.4.4 Modes of Cultural Transmission

Contrary to prediction, interviews with ten adults, including five adult "innovators" and 20 adolescents, informal observations, and limited video taping of teaching-learning sessions, suggest that adolescents learned new innovations from adults other than their parents (oblique transmission) or peers (horizontal transmission) and one to many. While the importance of vertical transmission, (parents teaching children) and horizontal transmission, (peer, intergenerational, a characteristic form of transmission in adolescence) cannot be overemphasized, given that the innovators were adults other than parents, most transmission of new knowledge or invention occurred obliquely (for a more detailed analysis of social learning among foragers see Hewlett 2013; Hewlett et al. 2002, 2011).

11.4.5 Processes of Social Learning

The 20 adolescents were asked during structured interviews how they learned a specific set of 20 skills and tasks (e.g. how to construct a basket, how to make a drum, how they learned a new song/dance). Observation, and imitation with limited verbal instruction of a new trait (e.g. the adolescent observes and imitates the adult, who demonstrates the task and gives some verbal instruction) was reported as occurring 14 times during the learning of the 20 tasks in which the adolescent was taught a novel behavior or skill. Imitation only, (e.g. observing a new dance step and imitating it without instruction), occurred six times during the learning of the 20 tasks and direct demonstration ("hand-to-hand") instruction (e.g. adult innovator sits side by side adolescent demonstrating a technique, has the adolescent perform the task and guides the learner's hands in the correct method, see Fig. 11.1) was reported by the adolescents as occurring four times during the learning of the 20 skills or tasks, much less frequently than either observation with verbal direction or observation, demonstration and imitation.

Aka adolescents described a diversity of modes of social learning processes: an Aka adolescent female illustrates learning by observation, and imitation, "He sings good songs about love and respect. I learned his songs and dances but didn't pay. I watched him and learned. He didn't teach me." An adolescent male describes receiving directed instruction, "M. says, 'See the way I dance and sing.' When he is singing and dancing he says, 'watch how I do this, how I sing and how I dance.' He has the learner try and he watches them. If learner makes a mistake he repeats it again, repeats, repeats, until the learner gets it correct. He says, 'stand together with me and try to dance with me.'" This style of direct instruction was more common than other methods when the adolescents were learning more complex skills and tasks such as basket and drum manufacture. Often the "teacher" would demonstrate a task, then have the "student" repeat the same task until it was correctly reproduced. For example,

Fig. 11.1 Hand-to-hand instruction of basket weaving

> First I make a small amount then I give it to the student to try. When they make it wrong, I take it and make it again and they see and I tell them to try again. (Aka adult male identified by the adolescents as an innovator).

Adolescents also described learning by direct demonstration ("hand-to-hand") instruction; "I watched, then E. took my hand with the bag and together we made it" (Aka adolescent male).

11.4.6 Adolescent Choice and Strategies of Learning

Twelve out of twenty adolescents said that they sought out the "best" teachers, either in their own camp, nearby camps, or in camps some distance away (i.e. several days walk). The adolescents explained that they preferred those adult teachers, who they may or may not personally know or be related to, but who the adolescents directly observed or who had a reputation as a good teacher and/or innovator. Adolescents described the "best" teachers as those who were patient, taught slowly, gave directed instruction and ensured the student correctly performed the new task. Adolescent's choices of individuals from whom to learn innovations were based upon types/complexity of skills being taught, the innovativeness of the person, and teaching ability. For example, one adolescent male said, "He is a good teacher, he has a good way to teach a person… He goes slow, slow. He watches how I do this, if I make a mistake, he makes me repeat and repeat until it is the right way." Adolescents were likely to choose those who exhibited pro-social characteristics (kindness [empathetic, generous], and quietness [calm, approachable]) and were seen as wanting to help others. Males were more likely to learn from adult males, while females chose both adult males and females; "I choose to learn from people who do good. I choose the best thing. It is important, I want to learn from people who have special knowledge," (Aka adolescent female). As predicted, both adolescent males and females chose skillful others, albeit adults, to learn from. Learning from others, and choosing from whom to learn was self-directed as illustrated by an older adolescent male, "I choose who to learn from. If I see someone who knows better how to make a new song or basket, I approach them to learn from this person who does this best. I choose these particular people because they create new things and are good teachers."

11.4.7 Motivations for Adolescents to Learn Innovative Behaviors

Adolescents frequently listed mate attraction as the primary reason to learn innovative skills. As one adolescent girl explained, "To learn a new song and dance is good, if a *bokala* learns new things many women will love him. Girls will be interested in him. K. found a girl because of learning this new song and dance. I want to learn new dances, and dance well to find the boys." An adolescent male talked about the success his friend had in finding a girl, "He wanted to learn a new song and dance in order to find a girlfriend and he did, he found a girlfriend."

Adolescents were also more willing to pay money, or items (e.g. necklaces) to learn from those they regarded as the "best" at creating songs, dances, and new craft technologies, "M. is the *njamba*, the best. I have paid to learn *djenji*, he taught me the new song. I paid him a *makodi* (necklance) and 1,000 CFA, to find girlfriends." An adolescent female also related that she too had paid to learn, "I paid him because I used his time and I wanted to learn his special knowledge. I wanted to learn these special dances and songs to find boys."

Adolescents were also most keen to learn new innovations than were younger children or adults. As an older adolescent male explained, "*Bokala* (adolescents) want to learn new things more than older people or young people (children) to be successful in making a basket or cooking or hunting. We learn there are new ways to live, in life you have to know new things. You learn when you are young… It is good for our life now to learn new ways. When you learn something you get knowledge of life." Another adolescent added, "*Bokala* is the time to learn for your life. Old people learn too but it is difficult for them to understand very quickly because they have hard heads, but *bokala* and *ngondo* have quiet heads. It is easy for *bokala* to understand things, but older people have many programs and families and children. When you are *bokala*, the head is quiet and you are free to learn." Lastly, adolescents expressed that it was important to learn in order to gain a skill which they could use in the future to support (via trade or sale of item/skill) a family, "It is important for *bokala* to learn to prepare for when they will be married and get a family. They will be able to keep life."

11.4.8 Adult Versus Adolescent Innovation

Among the Aka foragers contrary to evolutionary and developmental predictions, qualitative and quantitative data indicate that innovations adopted by the group came from adults not adolescents, and that adults were more likely to be identified as innovators and to be sought out by the adolescents (Nasir 2005; Lewis 2008). Four adult males in particular were most frequently identified. Adolescent innovators were identified twice, and three adult female innovators were identified.

11.4.9 Gendered Innovation

Along four different trails with approximately 250–300 people on each trail, ten adolescent males identified 16 innovators, all who were adult males. Adolescent females identified 10 innovators, three were adult females, two were adolescent males. Additionally, adolescent males were less likely to seek out female innovators than were adolescent females.

11.5 Discussion and Conclusion

Innovation, as an element of behavioral plasticity, has been hypothesized to enhance the fitness and survivability of individuals, while overall increasing the diversity, and longevity of cultural traits overtime (Reader and Laland 2001). Human adolescents have species-specific social and cognitive abilities, learning and problem solving skills, creativeness, risk taking and exploratory behaviors, and are engaged in reputation building, mate attraction and selection, and social network building (Hewlett 2013). It is not surprising then that Aka adolescents seek out socially valued innovative knowledge and skills from "successful" others, innovators, potentially increasing their learning, adaptation and reproductive success. However, contrary to predictions, Aka adolescents were not the innovators. Innovations that were adopted by the group were more likely to come from middle-aged adult males. Thus, while Aka adolescents sought out "prestigious others" from amongst their peers to observe and emulate, when learning new innovative traits they sought out skilled and innovative adults, those adults who possessed special knowledge and ability that others did not. Reader and Laland (2001) likewise found in their extensive survey of the literature on primate behavior, that greater incidences of innovation occurred in adult primates rather than sub-adults and females. The authors suggest that adults may innovate more than young individuals "because innovation frequently builds on other skills, and requires a degree of experience…that is more common in adults than in younger primates" (2001, p. 802).

Another key point is that adolescents identified the innovators and chose from whom, and what, to learn. That is, learning was self-directed. Aka adolescents were adept at identifying, and sought out, knowledgeable adults (the most skilled) to learn from (oblique transmission and model biased learning (Chudek et al. 2012)). In every case but one these tended to be adults other than the adolescent's parents. Modeling studies suggest that cumulative culture will not occur in low population densities with limited migratory activity of subpopulations unless the offspring selects to learn from more knowledgeable adults other than parents (Powell et al. 2012, p. 143).

Explorative travel and risk taking behavior of older adolescents (particularly males) in many foraging populations effectively increases the "pool" of successful adults other than parents from whom to learn, enabling the accumulation of more complex skill sets and enhancing the social network and interconnectedness of populations (Henrich in O'Brien and Shennan 2010, p. 114; Powell et al. 2012, p. 143). Aka males have greater exploratory ranges than do Aka females, a pattern seen in other foraging groups (MacDonald and Hewlett 1999). Forager population density tends to be low, so older adolescent males have to travel farther to find potential mates. Because foragers generally marry in late adolescence, this is the time of long-distance travel. It is important to point out that risk taking exists during these exploratory treks. Travel is perilous, as any number of hazards can be encountered such as disease or injuries. Exploration not only increases mating chances, by increasing exposure to greater numbers of individuals, but also increases opportunities to observe and learn innovative traits. Traveling and exploration thus may lead to mating success, exposure to new innovations and establishment of broader social-economic-innovation networks. Exploratory and risk taking behavior are important features in the discussion of cumulative culture as these behaviors "facilitate cumulative knowledge" by increasing the numbers of others one will come into contact with—population increase by contact (Lewis and Laland 2012, p. 2175; Reader and Laland 2001). Reader and Laland found similar patterns of male biased innovation in nonhuman primates, and note that innovative behaviors for male primates may be a "less costly" and a more beneficial "fitness payoff" than for females (2001, p. 800). The authors suggest that this may be due to the fact that older adolescent males are more likely to take risks, and risk-taking behavior may lead to innovative behaviors (Reader and Laland 2001; Daly and Wilson 1983; for causes of death study see Hewlett et al. 1986).

Finally, the display of pro-social behaviors by innovators suggest strategies potentially related to fitness payoffs (Kaplan and Hill 1985; Inkeles 2000; Hill 2002; Gintis et al. 2003; Henrich and Gil-White 2001; Henrich et al. 2005). Additionally, these data lend support to the argument that individuals want to keep "owned" knowledge to themselves, the "cooperative dilemma" (Henrich and Gil-White 2001). Natural selection, Henrich and Gil-White argue, has acted to address this problem, in that learners pay those from whom they learn with "prestige deference." In an egalitarian foraging society practicing prestige avoidance, this takes the form of "small gifts, willingness to help, coalitional support" but not, I would argue with "public praise" as the authors suggest (Henrich 2010, p. 112). Autonomy and creativity are socially valued, public praise and deference to specific individuals, is not.

Recent work by cognitive psychologists suggest that one type of teaching, called natural pedagogy, is innate and a relatively unique trait of human cognition (Hewlett et al. 2011; Csibra and Gergely 2011). These data support the argument that not only does pedagogy exist in foragers, as was evidenced in systematic observations, video recordings and interviews with the Aka adolescents, but suggests that directed teaching enhances the "faithful transmission" of innovative traits between individuals. Additionally, adolescents listed character qualities of the innovators, which could be described as pro-social, indeed the simple act of innovation can be seen as pro-sociality, and sought out those individuals who exhibited those qualities as well as those who were "good teachers," utilizing teaching methods which would produce high fidelity cultural transmission of the innovative trait. Lewis and Laland's cultural transmission modeling study has shown that increasing the fidelity of social transmission of cultural traits between individuals plays an important role in the development of cumulative culture (Lewis and Laland 2012, p. 2175; Hewlett et al. 2011).

Adolescence as a new stage of human development in modern humans, may have arose as an adaptive product and maturational process of evolution in which cognitive development particular to the adolescent period-- flexible, creative, and abstract thought patterns, coupled with increasing exploratory ranging and risk taking behaviors, allowed adolescents to seek out new knowledge, innovations, and cultural skills from successful others, to look for new solutions to problems encountered in the rapidly changing environments of human adaptation (Bogin 2013; Ellis 2013). This would have enabled these modern *Homo sapien* adolescents to "solve strategic survival problems," by utilizing new inventions and new found ways of adapting to novel situations and rapidly changing ecologies, accelerating cultural evolution (Lewis 2008, p. 299; Barton et al., 2011, p. 705).

References

Barton CM, Riel-Salvatore J, Anderies JM, Popescu G (2011) Modeling human ecodynamics and biocultural interactions in the Late Pleistocene of Western Eurasia. Hum Ecol 39:705–725

Biondi IM, Bo MS, Vassallo AI (2010) Inter-individual and age differences in the exploration, neophilia and problem solving ability in a Neotropical raptor (*Milvago chimango*). Anim Cogn 13:701–710

Boesch C (1995) Innovation in wild chimpanzees. Int J Primatol 16(1):1–16

Boesch C (2003) Is culture a golden barrier between human and chimpanzee? Evol Anthropol 12:82–91

Bogin B (2013) Childhood, adolescence and longevity: a chapter on human evolutionary life history. In: Hewlett BL (ed) Adolescent identity: evolutionary, developmental and cultural perspectives. Routledge University Press, London

Chudek M, Heller S, Birch S, Henrich J (2012) Prestige-biased cultural learning: bystander's differential attention to potential models influences children's learning. Evol Hum Behav 33(1):46–56

Cole EF, Quinn JL (2012) Personality and problem solving performance explain competitive ability in the wild. Proc R Soc B 279:1168–1175

Csibra C, Gergely G (2011) Natural pedagogy as evolutionary adaptation. Philos T Roy Soc B 366:1149–1157

Daly M, Wilson M (1983) Sex, evolution and behavior, 2nd edn. Wadsworth, Belmont

Diamond J (1999) Guns, germs and steel. W.W. Norton & Co, New York

Ellis B (2013) Risky adolescent behavior: an evolutionary perspective. In: Hewlett BL (ed) Adolescent identity: evolutionary, developmental and cultural perspectives. Routledge, New York

Galef B Jr (1992) The question of animal culture. Hum Nature 3:157–178

Gintis H, Bowles S, Boyd R, Fehr E (2003) Explaining altruistic behavior in humans. Evol Hum Behav 24:153–172

Goodall J (1986) The chimpanzees of Gombe. Cambridge, Belknap

Henrich J (2001) Cultural transmission and the diffusion of innovations: adoption dynamics indicate that biased cultural transmission is the predominate force in behavioral. Am Anthropol New Ser 103(4):992–1013

Henrich J (2010) The evolution of innovation enhancing institutions. In: O'Brien M, Shennan SJ (eds) Innovations in cultural systems contributions from evolutionary anthropology. MIT, Cambridge, pp 99–120

Henrich J, Gil-White FJ (2001) The evolution of prestige: freely conferred deference as a mechanism for enhancing the benefits of cultural transmission. Evol Hum Behav 22:165–196

Henrich J, Boyd R, Bowles SC, Fehr E, McElreath R, Barr A, Smith N, Henrich N, Hill K, Gil-White F, Gurven M, Marlowe F, Patton J, Tracer D (2005) 'Economic man' in cross-cultural perspective: behavioral experiments in 15 small-scale societies. Behav Brain Sci 28(6):795–855

Hewlett BS (1992) Intimate fathers: the nature and context of Aka Pygmy paternal infant care. University of Michigan Press, Ann Arbor

Hewlett BL (2013) Adolescent identity: evolutionary, developmental and cultural perspectives. Routledge University Press, London

Hewlett BS, Cavalli-Sforza LL (1986) Cultural transmission among Aka pygmies. Am Anthropol 88:922–934

Hewlett BS, van de Koppel JMH, van de Koppel M (1986) Causes of death among Aka pygmies of the Central African Republic. In: Cavalli Sforza LL (ed) African pygmies. Academic, New York, pp 15–32

Hewlett BS, Silvertri A, Gugliemino CR (2002) Semes and genes in Africa. Curr Anthropol 43:313–321

Hewlett BS, Fouts H, Boyette A, Hewlett BL (2011) Social learning among Congo Basin hunter-gatherers. Philos Trans Roy Soc B 366:1168–1178

Hill K (2002) Altruistic cooperation during foraging by the ache, and the evolved human predisposition to cooperate. Hum Nature 13:105–128

Inkeles A (2000) Measuring social capital and its consequences. Policy Sci 33:245–268

Kameda T, Nakanishi D (2002) Cost–benefit analysis of social/cultural learning in a nonstationary uncertain environment. Evol Hum Behav 23:373–393

Kaplan H, Hill K (1985) Food sharing among Ache foragers: tests of explanatory hypothesis. Curr Anthropol 26:223–245

Katzir G (1982) Relationships between social structure and response to novelty in captive jackdaws, Corvus monedula, response to novel space. Behavior 81:231–263

Laland K, Reader S (1999a) Foraging innovation in the guppy. Anim Behav 57:331–340

Laland K, Reader S (1999b) Foraging innovation is inversely related to competitive ability in male but not in female guppies. Behav Ecol 10:270–274

Laland K, Reader S (2010) Comparative perspectives on human innovation. In: O'Brien M, Shennan SJ (eds) Innovations in cultural systems contributions from evolutionary anthropology. MIT, Cambridge, pp 37–52

Lewis J (2008) Ekila: blood, bodies and egalitarian societies. J Roy Anthropol Inst 14:297–315

Lewis HM, Laland K (2012) Transmission fidelity is the key to the build-up of cumulative culture. J Roy Anthropol Inst 367: 2171–2180

Liebenberg L (1990) The art of tracking: the origin of science. David Philip Publishers, Claremont

MacDonald DH, Hewlett BS (1999) Reproductive interests and forager mobility. Curr Anthropol 40:501–523

Morand-Ferron J, Cole EF, Rawles JEC, Quinn JL (2011) Who are the innovators? A field experiment with 2 passerine species. Behav Ecol 22:1241–1248

Nasir N (2005) Problem solving in technology-rich contexts: mathematics sense making in out-of-school environments. J Math Behav 24:275–286

Nishida T (1987) Local traditions and cultural transmission. In: Smuts SS, Cheney DL, Seyfarth RM, Wrangham RW, Strusaker TT (eds) Primate societies. University of Chicago Press, Chicago, pp 462–474

O'Brien M, Shennan SJ (2010) Innovations in cultural systems contributions from evolutionary anthropology. MIT, Cambridge

Powell A, Shennan S, Thomas MG (2012) Demography and variation in the accumulation of culturally inherited skills. In: O'Brien M, Shennan SJ (eds) Innovations in cultural systems contributions from evolutionary anthropology. MIT, Cambridge, pp 37–52

Reader S, Laland K (2001) Primate innovation: sex, age and social rank differences. Int J Primatol 22(5):787–805

Reader SM, Laland KN (2003) Animal innovation: an introduction. In: Reader SM, Laland KN (eds) Animal innovation. Oxford University Press, Oxford, pp 3–35

Rogers AR, Jorde LB (1995) Genetic evidence on modern human origins. Hum Biol 67:1–36

Tamnes CK, Ostby Y, Fjell AM, Westlye L, Due-Tonnessen P, Walhovd KB (2010) Brain maturation in adolescence and young adulthood: regional age-related changes in cortical thickness and white matter volume and microstructure. Cereb Cortex 20:534–548

Tennie C, Call J, Tomasello M (2009) Ratcheting up the ratchet: on the evolution of cumulative culture. Philos Trans Roy Soc B 364:2405–2633

Thornton A, Samson J (2012) Innovative problem solving in wild meerkats. Anim Behav 83:1459–1468

Tomasello M, Kruger A, Ratner H (1993) Cultural learning. Behav Brain Sci 16:450–488

Walker R, Hill K, Kaplan H, McMillan G (2002) Age-dependency in skill, strength and hunting ability among the Ache of eastern Paraguay. J Hum Evol 42:639–657

Part III

Human-Specific Learning Strategies and Cultural Evolution

Determinants of Cultural Evolutionary Rates

12

Kenichi Aoki

Abstract

The cultural Moran model is a simple stochastic model of birth, social learning, and death in a finite population, which assumes that one individual is born at a time, who then engages in social learning from the older individuals of the population, followed by the death of one individual other than the newborn. Using this model, we propose two different theoretical definitions for the cultural evolutionary rate. The first applies to the successive fixation of many discrete cultural traits, and the second to the change of one continuous cultural trait. Taking the case of random oblique transmission (a randomly chosen older individual is copied) as the baseline, we compare the effects of greater innovativeness and increased population size on the cultural evolutionary rate. With individuals capable of direct bias (a particular variant of a cultural trait is preferred and an older individual carrying that variant is identified and copied), the innovation rate is shown to be at least as important as—and in some cases much more so than—the population size in determining the cultural evolutionary rate. Moreover, the cultural evolutionary rate is predicted to increase as the number of acquaintances from whom social learning can occur increases, with the possible implication that a cultural trait that is normally acquired early in life may evolve more slowly than one that is normally acquired later. In addition, we show that one-to-many transmission (one older individual serves as the teacher to many novices) does not in itself have any effect on the cultural evolutionary rate. However, when the teacher is more innovative than others, increased population size has a small decelerating effect.

Keywords

Cultural moran model • Demography • Direct bias • Innovativeness • One-to-many transmission

12.1 Introduction

Numerous hypotheses attempt to explain the extinction of the Neanderthals and their replacement by modern humans (*Homo sapiens*). One distinction among the various hypotheses is whether they invoke competition between the two species or hold that Neanderthals would have gone extinct anyway due to climatic changes, etc. (e.g., Banks et al. 2008; Sørenson 2011; Stewart and Stringer 2012).

K. Aoki (✉)
Organization for the Strategic Coordination of Research and Intellectual Properties, School of Interdisciplinary Mathematical Sciences, Meiji University, 4-21-1 Nakano, Nakano-ku, Tokyo 164-8525, Japan
e-mail: kenaoki@meiji.ac.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_12, © Springer Japan 2013

The "learning hypothesis" seeks to account for the (competitive) replacement of Neanderthals by modern humans in terms of an innate difference in learning strategies (abilities) between the two species. It comprises three proposals: (1) there is an innate difference in the learning strategies employed by modern humans and Neanderthals; (2) the difference in learning strategies translates into the observed difference in cultural evolutionary rates and hence (an accumulation of) cultural content between the two species; (3) the difference in cultural evolutionary rates and the resultant difference in cultural content contributed significantly to the extinction of the Neanderthals and their replacement by modern humans.

Empirically, we know or suspect two things that are relevant to proposal 3. First, although the Paleolithic "culture gap" between Neanderthals and modern humans is rapidly closing (see Chap. 3)—for example, with the discovery that Iberian Neanderthals may have been using marine shells and mineral pigments in a symbolic way before the arrival of modern humans (Zilhão et al. 2010)—the instances of rapid cultural change, during the African late Middle Stone Age and European Upper Paleolithic, are nevertheless firmly associated with modern humans (Kuhn 2012; but see d'Errico and Stringer 2011). Second, replacements of modern human ethnic groups by other modern human ethnic groups in historical times—notably the European expansions into the Americas—were driven by differences in the cultural content of the competing groups and by demographic differences contingent on the differences in cultural content (Diamond 1997). Together these observations may suggest that, if Neanderthals and modern humans did indeed compete, the more culturally advanced modern humans would have prevailed.

Evolutionary theory cannot be used to prove proposal 1, the existence of an innate difference in learning strategies. Supporting evidence may eventually become available from paleo-neurological studies of size differences between Neanderthals and modern humans in the areas of the brain involved in individual learning and social learning. Similarly, it has been argued that shape changes during the growth of Neanderthal and modern human brains are different, which may entail that the neural connections that form are also different (Neubauer and Hublin 2012). On the other hand, ancient DNA studies (e.g., Green et al. 2010) may identify the critical genetic differences. Meanwhile, evolutionary theory can generate predictions as to what kinds of learning strategies are most likely to evolve under given environmental conditions, more specifically under given patterns of temporal and/or spatial environmental variability (e.g., Boyd and Richerson 1985; Rogers 1988; Feldman et al. 1996; Aoki and Feldman 2014). Then, in combination with empirical data on the environmental conditions experienced by modern humans and Neanderthals, which presumably were different, we can plausibly infer an innate difference in the learning strategies of the two species.

The specific theoretical question that we ask in this paper is: how does a learning strategy (at the individual level) determine the cultural evolutionary rate (at the population level). That is, we will be addressing proposal 2 of the learning hypothesis, interpreting this as a statement in logic. Before doing so, however, we need to explain what is meant by a learning strategy. Its components are individual learning (i.e., learning from personal experience; e.g., by trial-and-error or creative insight) and social learning (i.e., learning by copying others; e.g., by imitation). A learning strategy is the way in which individual learning and social learning are combined, either simultaneously or sequentially, and the relative dependence on each. The modes and biases of social learning are also integral components of a learning strategy. Using these terms, a short definition of cultural evolution is: the spread through social learning of innovations produced by individual learning. Our claim for an innate difference in learning strategies does not necessarily entail a major qualitative difference in cognition, as has been suggested by Mithen (1996).

In this paper are summarized the results of two theoretical studies conducted by us (Aoki et al. 2011; Kobayashi and Aoki 2012), which show that the innovation rate (the rate at which a new or variant "cultural trait" is produced) contributes perhaps most strongly to the cultural evolutionary rate. Since a higher innovation rate requires a more advanced aptitude for individual learning, this result entails that Neanderthals were relatively deficient in individual learning compared to modern humans, whereas they could have been equally adept at social learning.

Others researchers have argued, sometimes inaccurately, the importance of the modes and biases of social learning. Thus, the "one-to-many" mode of social transmission where several, perhaps highly-skilled, individuals each serve as the "teacher" to many novices (Guglielmino et al. 1995; Lycett and Gowlett 2008), and "direct bias" where an individual with the preferred, often the "best," variant of a cultural trait is identified and copied (Henrich 2004; Powell et al. 2009; Mesoudi 2011) have been claimed to increase the cultural evolutionary rate. The distinction between mode and bias may sometimes be subtle. For example, direct bias often entails one-to-many transmission, but not vice versa, since the teacher may be skilled in the non-preferred variant. One purpose of this paper is to reexamine the effect of the modes and biases on social learning on the cultural evolutionary rate with these qualifications in mind.

With individuals capable of direct bias, demographic parameters such as total population size and the number of acquaintances are also expected to affect the cultural evolutionary rate (Henrich 2004; Powell et al. 2009; Mesoudi 2011; Kobayashi and Aoki 2012). The relevance of such factors—i.e., modes and biases (also pathways) of social learning; demographic parameters—is not just a theoretical question, but also an empirical one that needs to be resolved by archaeological and cultural-anthropological studies of past and present hunter-gatherers (Pigeot 1990; Henrich and Broesch 2011; Marlowe 2005; Hamilton et al. 2007; Hill et al. 2011). Theoretically speaking, however, these factors may not be as crucial as the innovation rate in determining the cultural evolutionary rate (Aoki et al. 2011; Kobayashi and Aoki 2012). Moreover, we wish to emphasize that, depending on the modes and biases of social learning, the cultural evolutionary rate may be unaffected by demographic parameters.

12.2 Cultural Moran Model and the Cultural Trait

In order to obtain the cultural evolutionary rate associated with a learning strategy, we require a demographic model incorporating birth, social learning, and death in a finite population of size N, corresponding to a "tribe" or "ethnolinguistic group" (see Sect. 12.4.2 for details). (It is also necessary to specify how innovations are produced.) The demographic model should, as far as possible, be mathematically tractable and a faithful representation of the hominid condition. We invoke the cultural Moran model (Strimling et al. 2009; Lehmann et al. 2011; Aoki et al. 2011), which is derived from the Moran model of population genetics (Moran 1958). In this model, one individual is born at a time, who then engages in social learning of a cultural trait or traits from the older individuals of the population. Then, one of the N older individuals is randomly chosen to die (we ignore viability differences). The birth of an individual, followed by social learning by that individual and the death of an individual other than the newborn, define one *time step*. One virtue of the cultural Moran model is that the generations are naturally overlapping—e.g., an individual can be alive at the same time as his/her parents and children—which provides a closer approximation to hominid demography than the earlier models of cultural transmission that assumed discrete non-overlapping generations (Cavalli-Sforza and Feldman 1981).

Since deaths occur at random, the life expectancy of a newborn is N time steps. Hence, N time steps are equivalent in duration to one generation (Gale 1990). This does not mean that the lifespan of an individual increases linearly with population size. Rather, the correct interpretation is that the interval between successive births decreases in inverse proportion to the population size. An alternative way of establishing correspondence between the discrete- and overlapping-generations models is to note that social learning occurs exactly N times during the N time steps. Here, we recognize another virtue of the cultural Moran model, which is that a cultural change occurring during one generation can be decomposed into N smaller cultural changes each occurring during one time step, thus facilitating mathematical analysis.

Two different measures of the cultural evolutionary rate will be considered in this paper (see Sects. 12.3 and 12.4). Any definition of the cultural evolutionary rate is closely linked to how one conceptualizes a cultural trait. We follow Cavalli-Sforza and Feldman (1981, p. 73) in defining a cultural trait operationally as "the result of any cultural action … that can be clearly observed or measured on a discontinuous or continuous scale." Hence, the length, width, and thickness of a stone tool, for example, can each be regarded as a cultural trait. In a similar vein, Jordan and Shennan (2009) distinguish 46 cultural traits the presence or absence of which can be used to describe a cradle. A more restrictive definition of a cultural trait has recently been suggested by O'Brien et al. (2010) that equates a cultural trait to a recipe (in the case of a stone tool, for example, this recipe would include knowledge of the materials, instructions for preparing these materials, knowledge needed to construct the tool, etc.).

12.3 Long-Term Cultural Evolutionary Rate for Discrete Cultural Traits

12.3.1 Generalities

The rate of genetic (molecular) evolution viewed over a long time is estimated by counting the (large) number of mutant substitutions and dividing this number by the elapsed time. Similarly, for studies of cultural evolution based on empirical observations in the archaeological record or inferences from differentiation of contemporary populations, the accumulated differences in many cultural traits (e.g., morphometric data on handaxes, design traits of canoes) are examined to obtain an estimate of the cultural evolutionary rate (Guglielmino et al. 1995; Eerkens and Lipo 2007; Lycett and Gowlett 2008; Rogers and Ehrlich 2008; Rogers et al. 2009; Jordan and Shennan 2009).

Drawing on this analogy between how the rates of genetic and cultural evolution are measured in practice, Aoki et al. (2011) proposed that the long-term *theoretical* rate of cultural change, R, should be defined as

$$R = Nu\pi_1 \tag{12.1}$$

Equation (12.1) is based on the "infinite site(s) model" of population genetics (Kimura 1969), where in the current context N is the population size, u is the innovation rate per individual per generation, and π_1 is the fixation probability of an innovation that is initially made by a single individual. By innovation is meant a new variant of a pre-existing non-variable cultural trait, or alternatively an entirely new cultural trait. By fixation is meant the spread through the population of the innovation until it is shared by all members of the population. The intuitive meaning of Eq. (12.1) is clear: a total of Nu innovations arise in the population during one generation of which the fraction π_1 is eventually fixed.

Equation (12.1) entails that innovations are produced and spread through the population independently of each other. Although this assumption has been shown not always to hold in empirical studies (e.g., Brown and Feldman 2009; Jordan and Shennan 2009), Eq. (12.1) is still conceptually useful as a point of departure for future theoretical work, because it provides a summary statement relating three important factors that contribute to the cultural evolutionary rate.

Aoki et al. (2011) extend Eq. (12.1) to the case where there are different social roles (e.g., male and female, more than one age class, teacher and non-teacher). If there are m different social roles, the appropriate generalization of Eq. (12.1) is

$$R = \sum_{i=1}^{m} N_i u_i \pi_{1i} \tag{12.2}$$

where N_i is the number of individuals in role i, u_i is the innovation rate of an individual in role i, and π_{1i} is the fixation probability of an innovation made by an individual in role i.

The fixation probability (π_1 or π_{1i}) is determined by the modes and biases of social learning, as described below.

12.3.2 A Model of Random Oblique Transmission

Assume that a cultural trait exists in two alternative forms, type A and type B. Type A represents the new variant of the cultural trait and type B the old variant. Alternatively, type A can correspond to the presence of a cultural trait and type B to its absence.

Recall that in the cultural Moran model, each time step comprises birth, social learning, and death. Let there be i type A individuals and $N-i$ type B individuals in the population of size N at the beginning of a time step. The newborn is naïve. Random oblique transmission entails that an individual copies, by social learning, a randomly chosen member of the population into which it is born. Mathematically, this means that he/she acquires type A with probability i/N and type B with the complementary probability $(N-i)/N$. Hence, after social learning the number of type A individuals (in the extended population of size $N+1$) is either i (no change) or $i+1$ (increment by one). Then one of the N older individuals dies (and the population reverts to size N). Since deaths are assumed to occur at random (without viability differences but excluding the newborn), the probability a type A individual dies is i/N and the probability that a type B individuals dies is $(N-i)/N$.

Thus, at the end of the time step there are either $i-1$, i, or $i+1$ type A individuals in the population. The probability that the number of type A individuals has increased by one (up-transition) is

$$p_i = i/N \times (N-i)/N, \tag{12.3}$$

which is the product of the probability, i/N, that the newborn acquires type A and the probability, $(N-i)/N$, that mortality strikes a type B individual. Similarly, the probability that the number of type A individuals has decreased by one (down-transition) is

$$q_i = (N-i)/N \times i/N, \tag{12.4}$$

and the probability that the number has not changed is, of course, $1-p_i-q_i$.

Standard mathematical method (Ewens 2004; see also Aoki et al. 2011) applied to Eqs. (12.3) and (12.4) yields the fixation probability of type A when there are initially i type A individuals in the population. We obtain the simple result,

$$\pi_i = i/N. \tag{12.5}$$

(Note that social roles are not differentiated in the model of random oblique transmission, so there is only the one fixation probability.) In particular, when there is initially a single type A individual, this formula reduces to

$$\pi_1 = 1/N. \tag{12.6}$$

Hence, on substitution of Eq. (12.6) into Eq. (12.1), the population size and the fixation probability cancel exactly, and we find that the cultural evolutionary rate under random oblique transmission is very simply

$$R = u. \tag{12.7}$$

In words, the cultural evolutionary rate is equal to the innovation rate and does not depend on the population size.

With random oblique transmission, the newborn literally chooses his/her exemplar at random. There are no constraints on who may serve as exemplars, and no preferences are expressed with regard to the cultural trait. Hence, the case of random oblique transmission serves as a baseline against which the effect of various modes and biases of social learning on the cultural evolutionary rate can be assessed.

12.3.3 A Simple Model of Direct Bias

Direct bias is a kind of social learning bias in which a particular variant of a cultural trait is preferred and an individual carrying that variant is identified and copied (Boyd and Richerson 1985). As before we assume two forms, type A

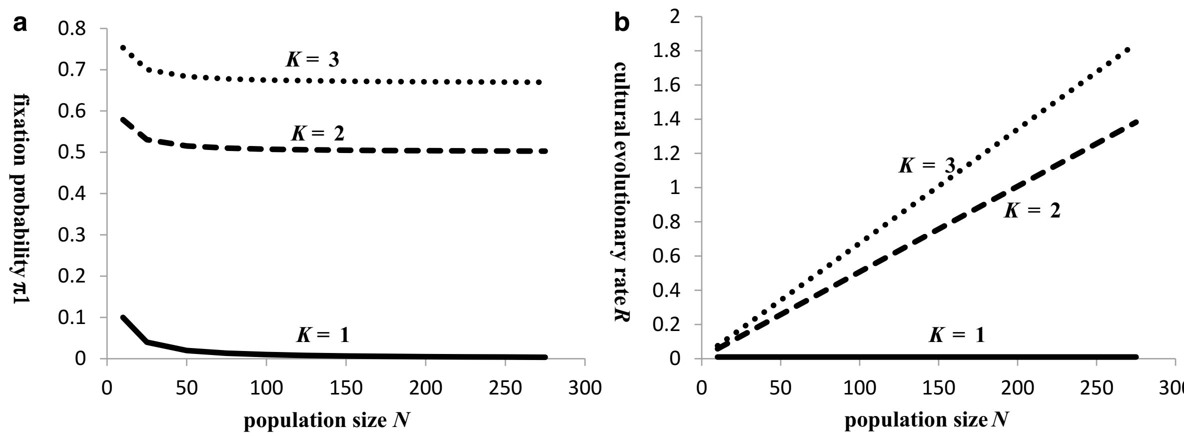


Fig. 12.1 (**a**) Fixation probability of an innovation made by a single individual, π_1, is plotted against the population size, N (≥ 10), for the simple model of direct bias (Sect. 12.3.3). Parameter K is the number of older individuals sampled by a newborn. The case of $K=1$ corresponds to random oblique transmission (Eq. (12.6) of Sect. 12.3.2). (**b**) Cultural evolutionary rate, R, is plotted against the population size, N (≥ 10), for the simple model of direct bias (Sect. 12.3.3). The plots for $K=2$ and $K=3$ are approximately linear increasing functions of N with intercept 0. Innovation rate is arbitrarily set at $u=0.01$

and type B, of a cultural trait, where type A represents the innovation. This variation may be purely stylistic, and for the sake of simplicity we ignore any associated fitness differences, although it is possible to take natural selection into account (Aoki et al. 2011). Moreover, we assume that all individuals share a preference for type A. In other words, the new variant of a pre-existing cultural trait or the presence as opposed to the absence of a new cultural trait is preferred. Hence, direct bias in the current context is synonymous with a pro-novelty bias.

Specifically, we assume that a newborn samples K individuals without replacement from the population of N older individuals ($2 \leq K \leq N$) and adopts type A provided there is at least one individual of type A among these K individuals. If type A individuals are absent from this sample, the newborn perforce adopts type B. With these assumptions, the probabilities of adoption of type A or type B by the newborn can be expressed in terms of the hypergeometric distribution. Then, noting that deaths occur at random, we can repeat the argument used with the model of random oblique transmission to obtain the up- and down-transition probabilities, the fixation probability, and finally the cultural evolutionary rate for the current model.

The formula for π_1 is complicated, except in the special case of $K=N$ (the newborn samples all individuals) where it reduces to $\pi_1=1$. This special case yields the simple formula

$$R = Nu \qquad (12.8)$$

for the cultural evolutionary rate, which is exactly linear in both N and u. That is, a proportional change in the population size and a proportional change in the innovation rate have exactly the same effect on the cultural evolutionary rate.

Rather than write the general formulas for π_1 and R explicitly when $K<N$ (see Aoki et al. 2011), we provide numerical examples in Fig. 12.1a, b, respectively, for comparison with the baseline case of random oblique transmission. Details are provided in the figure legend. The important results are: (1) the fixation probability, π_1, is much larger than for the case of random oblique transmission and increases as the number of acquaintances, K, increases (Fig. 12.1a); (2) the cultural evolutionary rate, R, increases almost linearly as the population size, N, increases, and the intercept is approximately zero (Fig. 12.1b). (Values of π_1 and R cannot be explicitly calculated for N greater than about 275 due to rounding errors, but there is no reason to suspect the trend will not continue.) Clearly, demographic factors cannot be ignored when direct bias exists, unlike the situation with random oblique transmission in which the cultural evolutionary rate is entirely determined by the innovation rate.

Dependence on the innovation rate is exactly linear for all values of K and with intercept zero, since the quantity $N\pi_1$ in Eq. (12.1) is independent of u. Hence, in this general case of $K<N$, we again find that the effects of population size and innovation rate on the cultural evolutionary rate are comparable.

In this model of direct bias, we have assumed a preference for the innovation, perhaps because it is an "improvement" over the old variant of a cultural trait or the absence of the cultural trait. However, it may be argued that not all innovations are of this kind, and that some are preferentially neutral while others are eschewed. The former category of innovations would be socially learned by random oblique transmission and hence follow the population dynamics described in Sect. 12.3.2. Nevertheless, given the large disparity between the fixation probabilities with direct bias and with random oblique transmission (Fig. 12.1a), especially when population size is large, we can argue in analogy with Kimura (1983, p. 100) that preferentially neutral innovations will contribute little to cultural evolutionary change. A fortiori, innovations that are eschewed would contribute even less. Hence, we expect that our prediction regarding the relative effects of population size and innovation rate on the cultural evolutionary rate will continue to hold.

12.3.4 A Simple Model of One-to-Many Transmission

We posit a simple model of one-to-many transmission where just one individual in a population of size N has the special status of teacher at any one time. This is an extreme assumption. Pigeot (1990) suggests that perhaps one skilled knapper instructed all other individuals in stone-tool-making at the Magdalenian archaeological site of Etiolles. If an archaeological site reflects the activities of a subgroup of the tribe such as a band or several families (see Sect. 12.4.2 for details), then there would be more than one teacher in the population. Nevertheless, it is of interest—even under this extreme assumption—to investigate the effect, if any, of limiting the number of exemplars (cultural parents) on the cultural evolutionary rate.

The details of this model are as follows. Each individual is distinguished by whether he/she is the teacher or a non-teacher and by the variant of the cultural trait, type A or type B, that he/she carries. At each time step, one newborn is produced who adopts the variant of the cultural trait carried by the current teacher, followed by the death of one random individual excluding the newborn. If the teacher is the one to die, his/her social role is taken by another individual, chosen from among the survivors. The new teacher is chosen randomly with regard to the variant of the cultural trait that he/she carries. On the other hand, it is permissible, although not necessary, to assume that the selection of the new teacher is based on his/her skill or innovativeness.

Since there are two social roles, teacher and non-teacher, in this model, we require two fixation probabilities. As shown by Aoki et al. (2011), the fixation probability of an innovation made by the one teacher is

$$\pi_{1A} = (N+1)/(2N), \qquad (12.9)$$

and the fixation probability of an innovation made by one of the non-teachers is

$$\pi_{1B} = 1/(2N). \qquad (12.10)$$

(The subscripts A and B in Eqs. (12.9) and (12.10) indicate that the teacher carries type A and type B, respectively.) Equation (12.9) shows that the fixation probability is high (greater than one-half) when the teacher is the innovator. By contrast, Eq. (12.10) shows that the fixation probability is low (one-half of Eq. (12.6) in the model of random oblique transmission) when the innovation is made by a non-teacher. The reason for the latter low value is that an innovation made by a non-teacher can only begin to spread through the population if and when that non-teacher becomes the teacher.

To obtain the cultural evolutionary rate, we apply Eq. (12.2). There is one teacher and $N-1$ non-teachers. Let us assume that the innovation rates of the teacher and non-teachers may differ, denoting them by u_t and u_{nt}, respectively. Then, recalling Eqs. (12.9) and (12.10), the cultural evolutionary rate can be written as

$$R = \left[u_t (N+1) + u_{nt} (N-1)\right] / (2N). \qquad (12.11)$$

In order to compare Eq. (12.11) with the baseline Eq. (12.7) (for the model of random oblique transmission), let assume that non-teachers who form the majority of the population innovate at rate $u_{nt} = u$. Equation (12.11) is essentially an arithmetic average of u_t and u_{nt} for large N. Hence, the cultural evolutionary rate with one-to-many transmission cannot exceed the baseline value of $R = u$ unless $u_t > u_{nt}$. That is, unless a teacher is more innovative than a non-teacher. In particular, if $u_t = u_{nt} = u$, then Eq. (12.11) reduces exactly to $R = u$.

We conclude that one-to-many transmission per se does not have an accelerating effect on cultural evolution and that it is necessary to make the additional assumption that a teacher is more innovative than a non-teacher for it to do so. Given the emphasis on demographic parameters in recent reviews of cultural evolutionary rates during the Paleolithic (d'Errico and Stringer 2011; Kuhn 2012), it is also of interest to note that Eq. (12.11) is a decreasing function of the population size, N, when $u_t > u_{nt}$.

12.4 Cumulative Evolution of a Continuous Cultural Trait

12.4.1 Modified Henrich Model

Henrich (2004) investigated the effects of direct bias and population size on the cumulative evolution of a continuous cultural trait using a discrete-generations stochastic model. Here we describe a modified version of the Henrich model that is based on the cultural Moran model and incorporates overlapping generations (Kobayashi and Aoki 2012).

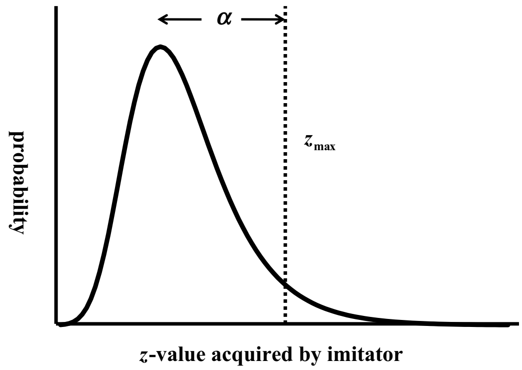


Fig. 12.2 Distribution of the possible z-values acquired by a newborn imitating an exemplar (cultural parent) whose z-value is z_{max}. Parameter α measures the deviation of the mode from z_{max}. Parameter β (not shown) is proportional to the standard deviation of the distribution. The area under the curve to the right of z_{max} is the innovation rate, φ

Assume a population of N individuals, with each of whom is associated a z-value that measures a culturally-determined continuous trait carried by that individual. It is assumed that larger z-values are in some sense "better." Examples are foraging efficiency, skill in stone-tool-knapping, etc. Direct bias in this context refers to a preference for the maximal z-value in the population, which we denote by z_{max}. We believe that direct bias is the appropriate term to describe the kind of social learning bias modeled here, since a naïve individual chooses his/her exemplar based only on the competence of that exemplar in the specific cultural trait that is to be copied. No other criteria or attributes of the exemplar, such as prestige or overall success, are utilized in this choice.

As before, each time step begins with the birth of one individual. The newborn successfully identifies the older individual whose z-value is z_{max} (from among the N older individuals) and attempts to imitate him/her. However, social learning is noisy and biased so that the z-value acquired by the newborn deviates probabilistically from the z-value of the exemplar (i.e. z_{max}), and is on average lower. Nevertheless, and importantly, the z-value of the newborn imitator may exceed that of the exemplar. Error-prone social learning of this nature—where the imitator can occasionally surpass the exemplar—can be interpreted as encompassing exploratory individual learning as well as social learning.

Specifically, it is assumed that the z-value acquired by the newborn follows a Gumbel distribution (see Fig. 12.2) with mode $z_{max} - \alpha$ and dispersion parameter β ($\alpha > 0, \beta > 0$). The mean of this distribution is $z_{max} - \alpha + \beta\varepsilon$ where $\varepsilon \approx 0.5772$, and the standard deviation is proportional to β. Parameter α can be regarded as a measure of the downgrade bias associated with social learning. Since the z-value acquired by the newborn is assumed to be lower on average than the z-value of the exemplar, we have $-\alpha + \beta\varepsilon < 0$ or equivalently $\alpha/\beta > \varepsilon$.

The probability that the z-value of the newborn imitator exceeds that of the exemplar is given by the area under the curve in Fig. 12.2 that lies to the right of the vertical broken line labeled z_{max}. It can be expressed as

$$\varphi = 1 - \exp\left(-e^{-\alpha/\beta}\right), \qquad (12.12)$$

which is a monotone decreasing function of α/β. When the imitator surpasses the exemplar, it is more appropriate to regard this as the result of innovation rather than of fortuitous error. Hence, we will refer to φ as the innovation rate (per time step). As in the simple model of direct bias considered above (Sect. 12.3.3), innovation is here defined as a change by learning of the z-value in the preferred direction (which exaggerates it beyond z_{max}).

Kobayashi and Aoki (2012) show that when N is large the expected change in z_{max} per generation (i.e., N time steps)—the cultural evolutionary rate—is given approximately by

$$\Delta z_{max} \approx N\beta f(\varphi), \qquad (12.13)$$

where φ is the innovation rate defined by Eq. (12.12), and

$$f(\varphi) = -\varphi \cdot \alpha/\beta - \int_0^{e^{-\alpha/\beta}} e^{-y} \log y\, dy. \qquad (12.14)$$

Equation (12.14) and hence Eq. (12.13) are always positive, despite appearances. The function $f(\varphi)$ depends only on φ, since α/β can be expressed in terms of φ using Eq. (12.12).

From Eq. (12.13) it is clear that the cultural evolutionary rate, Δz_{max}, is approximately proportional to the population size, N. For example, a fivefold increase in the population size entails a roughly fivefold increase in the cultural evolutionary rate. This result is reminiscent of the linearity observed in the simple model of direct bias (Eq. (12.8) for the case of $K = N$; see also Fig. 12.1b for the case of $K < N$).

The effect of the innovation rate is not straightforward. In Fig. 12.3 we plot $f(\varphi)$, evaluated by numerical integration, against φ (where $\varphi < 0.4296$ corresponding to the constraint $\alpha/\beta > \varepsilon \approx 0.5772$). Figure 12.3 shows that $f(\varphi)$ increases almost linearly in φ with a slope that is slightly larger than one and an intercept of zero. However, this does not assure that the relationship between Δz_{max} and φ is approximately linear, since Δz_{max} also depends on β [see Eq. (12.13)]. Although φ uniquely determines the ratio α/β, the individual values of α and β are not determined [see Eq. (12.12)]. For example, two among an infinite number of ways to achieve a value of $\varphi = 0.05$ for the innovation rate are: $\alpha = 2.970$ with $\beta = 1$, and $\alpha = 4.600$ with $\beta = 1.549$. Since $f(0.05) = 0.0506$, Eq. (12.13) entails that $\Delta z_{max} = N \times 1 \times 0.0506 = N \times 0.0506$ in the former case, whereas $\Delta z_{max} = N \times 1.549 \times 0.0506 = N \times 0.0784$ in the latter case.

Innovativeness defined by Eq. (12.12) is a decreasing function of α and an increasing function of β. Figure 12.2 suggests the following biological meanings of these parameters. First, a smaller value of α implies greater fidelity in social learning, or

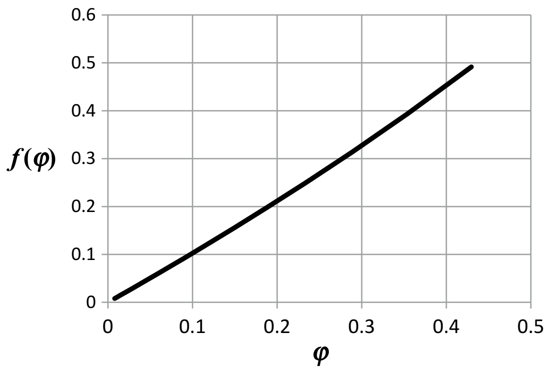


Fig. 12.3 Function of the innovation rate, φ, defined by Eq. (12.14). The integral in Eq. (12.14) was evaluated numerically as $-\varepsilon - \int_{e^{-\alpha/\beta}}^{UB} e^{-y} \log y dy$, where $\alpha/\beta = -\log(-\log(1-\varphi))$ and UB is a large number

alternatively more compensation by individual effort for the downgrade bias associated with social learning. Second, a larger value of β signifies either reduced accuracy in social learning, or heightened exploratory behavior accompanying trial-and-error learning. Hence, varying β has opposite effects on social learning and innovativeness, whereas a smaller value of α entails improvements in both. In our view, these considerations suggest that β, rather than α, is perhaps the less ambiguous (positive) correlate of innovativeness.

Let us accept this argument and assume that variation in φ is associated with variation in β. Then, Eq. (12.13) entails that a proportional change (e.g., a fivefold increase) in φ has a greater—albeit of the same order of magnitude—effect than a proportional change in N on the cultural evolutionary rate, $\Delta z_{\max}$ (because β also changes in the former case but not in the latter).

12.4.2 Effect of the Number of Acquaintances

We extend the above model by introducing the more plausible assumption that only a subset of the population are known well enough and/or encountered sufficiently often to serve as exemplars for social learning (e.g., Read 2006). Hence, we assume that each newborn is acquainted with only K among the N older individuals, where $K<N$. Different newborns may have a different set of acquaintances

Valid choices for the population size, N, and the number of acquaintances, K, are constrained by what we know about the nested hierarchical structure of the present-day hunter-gatherers (e.g., Birdsell 1957; Dunbar 1993; Marlowe 2005; Hamilton et al. 2007; Hill et al. 2011; Hill 2012). Most authors recognize three levels of aggregation above the family (comprising an average of 4–5 individuals): the "band" (about 25–50 individuals), the "local community" (about 150 individuals), and the "tribe" or "ethno-linguistic group" (about 500–2,500 individuals).

The local community (Ichikawa 1978) is synonymous with the intermediate-level group predicted by Dunbar (1993), based on the neocortex ratio, and has a membership of about 150 individuals known as Dunbar's number. Both the band and the local community are characterized by fission-fusion, but the band may show more temporal persistence than the local community. The local community "may gather together once a year to enact rituals," and although an individual may have "direct personal knowledge" of its members (Dunbar 1993), opportunities for social learning may be limited. On the other hand, Hill (2012) argues that "hunter-gatherer society consists of many hundreds of individuals who know each other intimately and regularly interact in ways that allow cooperation and cultural transmission throughout the entire multi-band population." Clearly, we cannot dogmatically assign a specific value to the number of acquaintances variable, K, which moreover may show age-related changes (see below).

In addition, Lalueza-Fox et al. (2011) estimate the size of a possibly patrilocal Neanderthal group to be about 10, and as reported by Gibbons (2011), modern humans in Tanzania about 120,000 years ago may have traveled together in groups comprising one adult male and more than a dozen women and children.

We equate the population with the tribe. Tribes are open to external influences, genetic and cultural, but linguistic boundaries between tribes entail that most movement of and/or interactions between individuals occur within tribes (Marlowe 2005). Hence, it seems appropriate to regard the tribe as the population unit of cultural evolution.

The effect of the number of acquaintances, K, was investigated by Monte Carlo (i.e. agent-based) simulations. We assume that the K acquaintances of a newborn are randomly sampled from the population without replacement. Then from among the K acquaintances, the newborn identifies the one with the highest z-value, $z_{\max(K)}$—which will often be less than $z_{\max}$ of the population—and attempts to imitate him/her. The z-value acquired follows the Gumbel distribution with mode $z_{\max(K)} - \alpha$ and dispersion β. Sampling of the K acquaintances is done separately for each newborn. (Note the similarity of this agent-based model with the analytical model of Sect. 12.3.3.)

Figure 12.4 summarizes the results. The height of each bar depicts the average over 100 replications of the cumulative change in $z_{\max}$ during 100 generations (i.e., $100 \times \Delta z_{\max}$). For the number of acquaintances, we used the values $K=5$, 10, 25, 50, and 150, which correspond to the sizes of the ethnographically attested subunits of a population. We can clearly discern a trend toward greater cumulative increase as the number of acquaintances increases.

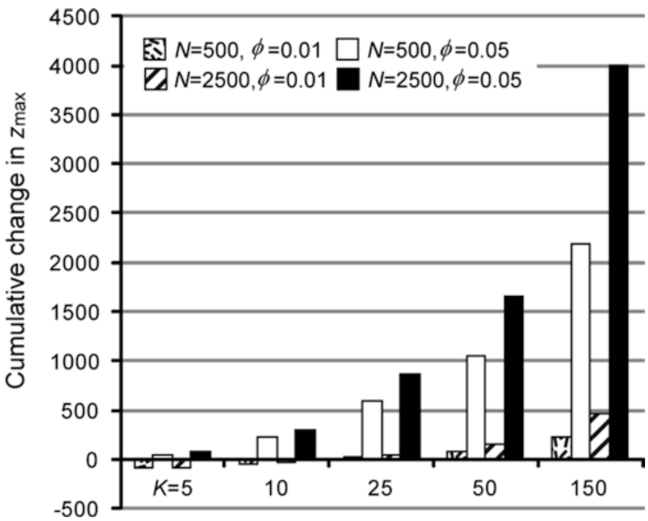


Fig. 12.4 Cumulative change in z_{max} is given for five values of K. The heights of each bar graph indicate the average over 100 replications of the Monte Carlo simulations. There is a trend toward a greater cumulative increase as K increases. Four bar graphs are depicted for each value of K, in order to compare the effects of fivefold variation in N and ϕ. The two population sizes are $N=500$ and $N=2,500$. The two innovation rates are $\varphi=0.01$ ($\alpha=4.600$ and $\beta=1$) and $\varphi=0.05$ ($\alpha=4.600$ and $\beta=1.549$). For example, the heights of the four bar graphs when $K=25$ are, from left to right, 12.2, 596.9, 47.8, and 868.8, showing a greater (non-additive) effect of varying ϕ

The main purpose of Fig. 12.4 is to compare the effects on the cumulative change in z_{max} of a fivefold increase in population size—from $N=500$ to $N=2,500$—and of a fivefold increase in the innovation rate—from $\varphi=0.01$ to $\varphi=0.05$. The increase in φ was achieved by changing β while holding α constant (specifically from $\beta=1$ to $\beta=1.549$ with $\alpha=4.600$; see above). Figure 12.4 shows that the effect of a fivefold increase in the innovation rate far exceeds the effect of a fivefold increase in the population size. This is particularly true when K is small.

Recall that Eq. (12.13) for Δz_{max} is an approximate formula. We can check the validity of this approximation by Monte Carlo simulations in which we set $K=N$. The results shown in Table 12.1 indicate good agreement, although Eq. (12.13) gives a slight overestimate, as may be expected from the approximation involved in its derivation (Kobayashi and Aoki 2012). When $K=N$, we can also see that changing the innovation rate or the population size has comparable—same order of magnitude—effects on $100\times\Delta z_{max}$.

Finally, it may be thought that the evolution of a continuous cultural trait, z, should more appropriately be investigated by tracking changes in the mean value, $\bar{z}$, rather than in the maximal value, z_{max}, as we have done. However, extensive simulations conducted by Kobayashi and Aoki (2012) show that for any set of parameter values the cumulative changes in $\bar{z}$ and z_{max} over 100 generations are nearly identical. Hence, our conclusions remain unaltered.

12.5 Discussion

The analyses presented in this paper are examples of the application of population genetics theory to cultural evolution (Cavalli-Sforza and Feldman 1981). We invoke the cultural Moran model (Lehmann et al. 2011; Aoki et al. 2011) to describe birth, social learning, and death in a finite population. The cultural Moran model is a more faithful representation of the hominid condition than the often-used discrete-generations models, since births occur singly rather than simultaneously, and consequently the generations are overlapping. Moreover, it is mathematically more tractable. Interestingly, the Moran model is in some regards better suited for dealing with cultural phenomena than with the genetic phenomena for which it was originally proposed (Moran 1958). The reason is that there are no constraints on ploidy (number of chromosome sets) or on the manner of reproduction—only on social learning—in the cultural version, whereas organisms in the genetic version must, rigorously speaking, be haploid and reproduce asexually.

Rapid cumulative change is believed to be an important feature of human culture (Tomasello 1999; Tennie et al. 2009). The three models of the successive fixation of innovations in many discrete cultural traits (Sects. 12.3.2–12.3.4) and the two models of the change of one continuous cultural trait with direct bias (Sects. 12.4.1 and 12.4.2) exhibit different forms of cumulativeness. The former are cumulative in a quantitative sense, whereas the latter entail sustained "improvement" of one specific trait and is cumulative in a qualitative sense. The two approaches to the modeling of cultural evolution are in fact quite different and capture different aspects of the cumulativeness of cultural change. Hence, they do not a priori have to yield the same predictions. Nevertheless, in the case of direct bias where a com - parison is possible (model of Sect. 12.3.3 and the models of Sects. 12.4.1 and 12.4.2), we have often observed close agreement. We therefore feel justified in discussing the predictions of the various models together under the assumption that they complement each other.

The baseline result is that the cultural evolutionary rate with random oblique transmission is equal to the innovation rate [Eq. (12.7)]. This situation may be viewed as unrealistic, for example, social learning in hunter-gatherers may occur preferentially from parents (vertical transmission) (Hewlett and Cavalli-Sforza 1986; Shennan and Steele 1999; Hewlett et al. 2011). However, random oblique transmission and vertical transmission are mathematically equivalent in the cultural Moran model, provided there are no fertility differences among the biological parents, as is assumed here (Aoki et al. 2011). To reiterate, demography does not affect the cultural evolutionary rate when social learning occurs from a randomly chosen exemplar and possibly also from parents.

Table 12.1 Comparing the effects of a fivefold increase in ϕ and/or N in the modified Henrich model when $K = N$

	$\phi = 0.01$ ($\alpha = 4.600$, $\beta = 1$)	$\phi = 0.05$ ($\alpha = 2.970$, $\beta = 1$)	$\phi = 0.05$ ($\alpha = 4.600$, $\beta = 1.549$)
$N = 500$	452.9 ± 31.6	2,475.8 ± 70.4	3,846.2 ± 103.4
	501.3	*2,532.2*	*3,921.7*
$N = 2,500$	2,443.6 ± 69.8	12,616.8 ± 163.8	19,515.8 ± 236.0
	2,506.3	*12,660.7*	*19,608.6*

In each of the six cells, the upper entry is the mean and standard deviation of the change in z_{max} during 100 generations over 100 replications of the Monte Carlo simulations. The lower italicized entry is the value calculated from the approximate analytical formula Eq. (12.10)

Let us now consider the effects of the innovation rate and the population size when there is direct bias. Direct bias means that a particular variant of a cultural trait is preferred and an individual carrying that variant is identified and copied. The preferred variant is often the most skillfully produced version of an artifact, and this entails that a naïve individual can recognize competence in a specific task. Studies in the laboratory (Mesoudi 2009; Chudek et al. 2012, for review) and in the field (Henrich and Broesch 2011) may suggest that present-day humans possess this ability, although it is difficult to distinguish in these studies whether the exemplars are chosen for their knowledge/skill in a specific activity (direct bias) or because of their overall success (indirect bias).

The models of Sects. 12.3.3 and 12.4.1 show that the cultural evolutionary rate in the presence of direct bias is proportional to the innovation rate, or may even increase with the innovation rate in a greater than linear fashion. Dependence on the population size is also approximately linear. In particular, if all individuals in the population know each other intimately, the innovation rate and the population size have comparable effects on the cultural evolutionary rate.

Still assuming direct bias, if the number of acquaintances from who social learning can occur is limited, the cultural evolutionary rate increases as the number of such acquaintances increases (see Figs. 12.1b and 12.4). According to Hewlett et al. (1982) who investigated the exploration ranges of Aka Pygmies, adolescents are significantly less mobile than adults. Hence, if exploration range correlates with the number of acquaintances, a possible implication of this theoretical result is that the evolutionary rate of a cultural trait normally acquired as an adolescent will be lower than that of a cultural trait normally acquired as an adult.

In addition, Eq. (12.1) and Fig. 12.1b for the simple model of direct bias (Sect. 12.3.3) entail that the innovation rate and population size have comparable effects on the cultural evolutionary rate. Equation (12.1) is linear in u so that a doubling, say, of the innovation rates results in a doubling of the cultural evolutionary rate. Similarly, Fig. 12.1b shows that a doubling of the population size produces a doubling of the cultural evolutionary rate. On the other hand, for the model of the change of one continuous cultural trait with direct bias (Sect. 12.4.2), we see from Fig. 12.4 that innovativeness has a much larger effect than population size when the number of acquaintances is limited.

Henrich (2004) argues for the role of demography, in particular population size, in accelerating cultural evolution (see also Powell et al. 2009; d'Errico and Stringer 2011; Kuhn 2012). Mellars and French (2011) estimate a tenfold difference in Neanderthal and modern human population sizes, which could have contributed to—or may have been the result of—a cultural difference between the two species. Theory reviewed in this paper suggests that innovativeness is at least as important as population size in determining the cultural evolutionary rate, which is consistent with the learning hypothesis.

Finally, with regard to the suggested accelerating effect of one-to-many transmission (Guglielmino et al. 1995; Lycett and Gowlett 2008), our theoretical analysis reveals a relatively small increase in the cultural evolutionary rate if teachers become teachers by virtue of their superior innovative abilities (see Chap. 11). However, it should be noted that our claim that one-to-many transmission per se does not have an accelerating effect is dependent on the way in which we define the cultural evolutionary rate as the long-term rate of substitution of many cultural traits [Eqs. (12.1) and (12.2)]. An alternative definition is as the rate of change in the frequency of a particular cultural trait. In the latter case, one-to-many transmission has a large effect on the cultural evolutionary rate, due to the reduction of the effective population size (Cavalli-Sforza and Feldman 1981, pp. 192–202; Aoki et al. 2011).

12.6 Closing Remark

The recent tendency in attempting to account for the periods of rapid cultural change during the Paleolithic is to invoke demographic factors such as population size. However, a careful reading of theory shows that an increase in population size does not necessarily predict an acceleration of cultural evolution. Whether or not it does depends on the modes and biases of social learning of cultural traits.

Acknowledgments I thank Marc Feldman for helpful comments. This research was supported in part by Monbukagakusho grant 22101004.

References

Aoki K, Feldman MW (2014) Evolution of learning strategies in temporally and spatially variable environments: a review of theory. Theor Popul Biol, in press

Aoki K, Lehmann L, Feldman MW (2011) Rates of cultural change and patterns of cultural accumulation in stochastic models of social transmission. Theor Popul Biol 79:192–202

Banks WE, d'Errico F, Peterson AT, Kageyama M, Sima A, Sánchez-Goñi M-F (2008) Neanderthal extinction by competitive exclusion. PLoS One 3:1–8

Birdsell JB (1957) Some population problems involving Pleistocene man. Cold Spring Harbor Symp Quant Biol 22:47–69

Boyd R, Richerson PJ (1985) Culture and the evolutionary process. University of Chicago Press, Chicago

Brown MJ, Feldman MW (2009) Sociocultural epistasis and cultural exaptation in footbinding, marriage form, and religious practices in early 20th century Taiwan. Proc Natl Acad Sci U S A 106: 22139–22144

Cavalli-Sforza LL, Feldman MW (1981) Cultural transmission and evolution. Princeton University Press, Princeton

Chudek M, Heller S, Birch S, Henrich J (2012) Prestige-biased cultural learning: bystander's differential attention to potential models influences children's learning. Evol Hum Behav 33:46–56

d'Errico F, Stringer CB (2011) Evolution, revolution or saltation scenario for the emergence of modern cultures? Phil Trans R Soc B 366:1060–1069

Diamond J (1997) Guns, germs, and steel. Norton, NewYork

Dunbar RIM (1993) Coevolution of neocortical size, group size and language in humans. Behav Brain Sci 16:681–735

Eerkens JW, Lipo CP (2007) Cultural transmission theory and the archaeological record: providing context to understanding variation and temporal changes in material culture. J Archaeol Res 15: 239–274

Ewens WJ (2004) Mathematical population genetics, 2nd edn. Springer, New York

Feldman MW, Aoki K, Kumm J (1996) Individual versus social learning: evolutionary analysis in a fluctuating environment. Anthropol Sci 104:209–232

Gale JS (1990) Theoretical population genetics. Unwin Hyman, London

Gibbons A (2011) Ancient footprints tell tales of travel. Science 332:534–535

Green RE, Krause J, Briggs AW et al (2010) A draft sequence of the Neandertal genome. Science 328:71–722

Guglielmino CR, Viganotti C, Hewlett B, Cavalli-Sforza LL (1995) Cultural variation in Africa: role of mechanisms of transmission and adaptation. Proc Natl Acad Sci U S A 92:7585–7589

Hamilton MJ, Milne BT, Walker RS, Burger O, Brown JH (2007) The complex structure of hunter-gatherer social networks. Proc R Soc B 274:2195–2202

Henrich J (2004) Demography and cultural evolution: how adaptive cultural processes can produce maladaptive losses—the Tasmanian case. Am Antiquity 69:197–214

Henrich J, Broesch J (2011) On the nature of cultural transmission networks: evidence from Fijian villages for adaptive learning biases. Phil Trans R Soc B 336:1139–1148

Hewlett BS, Cavalli-Sforza LL (1986) Cultural transmission among Aka pygmies. Am Anthropol 88:922–934

Hewlett B, van de Koppel JMH, Cavalli-Sforza LL (1982) Exploration ranges of Aka pygmies of the Central African Republic. Man (NS) 17:418–430

Hewlett BS, Fouts HN, Boyette AH, Hewlett BL (2011) Social learning among Congo Basin hunter-gatherers. Phil Trans R Soc B 366:1168–1178

Hill KR (2012) Social structure and inter-group interactions in hunter-gatherers: how humans achieved cumulative culture. In: the Wenner-Gren foundations international symposium "cultural evolution—patterns of cultural change and diversification"

Hill KR, Walker RS, Božičević M, Eder J, Headland T, Hewlett B, Hurtado AM, Marlowe F, Wiessner P, Wood B (2011) Co-residence patterns in hunter-gatherer societies show unique human social structure. Science 331:1286–1289

Ichikawa M (1978) The residential groups of the Mbuti pygmies. Senri Ethnol Stud 1:131–188

Jordan P, Shennan S (2009) Diversity in hunter-gatherer technological traditions: mapping trajectories of cultural 'descent with modification' in northeast California. J Anthropol Archaeol 28:342–365

Kimura M (1969) The number of heterozygous nucleotide sites maintained in a finite population due to steady flux of mutations. Genetics 61:893–903

Kimura M (1983) The neutral theory of molecular evolution. Cambridge University Press, Cambridge

Kobayashi K, Aoki K (2012) Innovativeness, population size and cumulative cultural evolution. Theor Popul Biol 82:38–47

Kuhn SL (2012) Emergent patterns of creativity and innovation in early technologies. In: Elias S (ed) Origins of human innovation and creativity. Elsevier, Amsterdam

Lalueza-Fox C, Rosas A, Estalrrich A etal (2011) Genetic evidence for patrilocal mating behavior among Neandertal groups. Proc Natl Acad Sci U S A 108:250–253

Lehmann L, Aoki K, Feldman MW (2011) On the number of independent cultural traits carried by individuals and populations. Phil Trans R Soc B 366:424–435

Lycett SJ, Gowlett AJ (2008) On questions surrounding the Acheulean 'tradition'. World Archaeol 40:295–315

Marlowe FW (2005) Hunter-gatherers and human evolution. Evol Anthropol 14:54–67

Mellars P, French JC (2011) Tenfold population increase in western Europe at the Neandertal—to—modern human transition. Science 333:623–627

Mesoudi A (2009) How cultural evolutionary theory can inform social psychology and vice versa. Psychol Rev 116:929–952

Mesoudi A (2011) Variable cultural acquisition costs constrain cumulative cultural evolution. PLoS One 6:1–10

Mithen S (1996) The prehistory of the mind. Thames and Hudson, London

Moran PAP (1958) Random processes in genetics. Proc Camb Phil Soc 54:60–71

Neubauer S, Hublin J-J (2012) The evolution of human brain development. Evol Biol 39:568–586

O'Brien MJ, Lyman RL, Mesoudi A, VanPool TL (2010) Cultural traits as units of analysis. Phil Trans R Soc B 365:3797–3806

Pigeot N (1990) Technical and social actors flintknapping specialists and apprentices at Magdalenian Etiolles. Archeol Rev Camb 9:126–41

Powell A, Shennan S, Thomas MG (2009) Late Pleistocene demography and the appearance of modern human behavior. Science 324:1298–1301

Read D (2006) Tasmanian knowledge and skill: maladaptive imitation or adequate technology? Am Antiquity 71:164–184

Rogers AR (1988) Does biology constrain culture? Am Anthropol 90: 819–831

Rogers DS, Ehrlich PR (2008) Natural selection and cultural rates of change. Proc Natl Acad Sci U S A 105:3416–3420

Rogers DS, Feldman MW, Ehrlich PR (2009) Inferring population histories using cultural data. Proc R Soc Lond Ser B 276:3835–3843

Shennan SJ, Steele J (1999) Cultural learning in hominids: a behavioural ecological approach. In: Box HO, Gibson KR (eds) Mammalian social learning: comparative and ecological perspectives. Cambridge University Press, Cambridge, pp 367–388

Sørenson B (2011) Demography and the extinction of European Neanderthals. J Anthropol Archaeol 30:17–29

Stewart JR, Stringer CB (2012) Human evolution out of Africa: the role of refugia and climate change. Science 335:1317–1321
Strimling P, Sjöstrand J, Enquist M, Eriksson K (2009) Accumulation of independent cultural traits. Theor Popul Biol 76:77–83
Tennie C, Call J, Tomasello M (2009) Ratcheting up the ratchet: on the evolution of cumulative culture. Phil Trans R Soc B 364:2405–2415
Tomasello M (1999) The human adaptation for culture. Annu Rev Anthropol 28:509–529
Zilhão J, Angelucci DE, Badal-Garcia E et al (2010) Symbolic use of marine shell and mineral pigments by Iberian Neandertals. Proc Natl Acad Sci U S A 107:1023–1028

Exploring Cultural Niche Construction from the Paleolithic to Modern Hunter-Gatherers

13

Nicole Creanza, Laurel Fogarty, and Marcus W. Feldman

Abstract

Niche construction is an evolutionary process through which organisms modify their environments, thereby altering the selection pressures on future generations. Cultural niche construction theory concentrates on those changes made by the spread of socially learned traits or to the evolutionary niche in which these learned traits evolve. We present a number of cultural niche construction models exploring important cultural processes that are either unique to, or uniquely well developed in, modern humans. We assess the role of these processes in the success of humans compared to other now extinct *Homo* species.

We concentrate particularly on cooperation, cooperative hunting, and active teaching. We show that teaching can increase the probability of a trait with marginal fitness benefits becoming fixed in the population, that this effect is strengthened by oblique transmission, and that teaching can increase the speed of cultural evolution.

Finally, we show that the evolution of cooperation is strengthened by homophily, in which cooperative individuals prefer to partner with other cooperators, and that strong transmission of cooperative norms can support the evolution of costly sharing practices through cultural niche construction.

Keywords

Cooperation • Cultural niche construction • Teaching

13.1 Introduction

Niche construction is the process by which the actions of an organism alter the evolutionary forces acting on its own species and potentially others. This process and its consequences have been extensively modeled (Odling-Smee et al. 2003). Ecological niche construction can lead to fixation of costly traits that would otherwise be deleterious (Laland et al. 1996, 1999, 2000), allow the persistence of populations in inhospitable environments (Kylafis and Loreau 2008) and change evolutionary dynamics in a number of other ways (see Odling-Smee et al. (2003) for an overview). The fast pace of cultural evolution also suggests that *cultural niche construction*—whereby members of a species, through accumulated socially learned traits, change their evolutionary niche or alter the niche in which the cultural traits themselves evolve—may be an important evolutionary force as well. The strength and pervasive nature of human culture may mean that cultural niche construction has been a potent driver of human evolution (Lewontin 1983; Laland et al. 1999, 2010; Ihara and Feldman 2004; Odling-Smee et al. 2003).

A well-documented example of cultural niche construction and gene-culture coevolution is the increase in frequency of the lactase persistence gene among early dairy agriculturalists (Simoons 1970; Aoki 1986; Feldman and Cavalli-Sforza 1989; Durham 1991). Here we examine other elements

N. Creanza (✉) • L. Fogarty • M.W. Feldman
Department of Biology, Stanford University, Gilbert Hall, Stanford, CA 94305-5020, USA
e-mail: creanza@stanford.edu; lfogarty@stanford.edu; mfeldman@stanford.edu

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_13,

of human cultural niche construction that may have contributed to the early success of modern humans relative to other hominids. In particular we focus on the evolution of two traits thought to have contributed to humans' success as a species, namely cooperative behaviors between individuals in a group and a capacity for fast and high fidelity information transmission and communication through teaching and imitation (Kurland and Beckerman 1985; Hill 2002). To do this, we draw on information from contemporary hunter-gatherer populations, whose high mobility, small group sizes, and relatively egalitarian structures have characterized 99 % of human history (Hewlett et al. 2011), along with paleoanthropological information on early modern humans and their predecessors. Note that the models dealing with these two traits differ slightly in structure. When considering cooperation, we model the coevolution of food sharing and cooperation, and when modeling teaching we consider the effects of a teaching trait on the evolution of another cultural trait.

13.1.1 Cooperative Hunting and Resource Sharing

The Ache are a foraging people living in eastern Paraguay (Hill and Hurtado 1996). In his 2002 paper on the cooperative gathering and hunting behavior of the Ache, Kim Hill wrote "In order to understand many special characteristics of our species that possibly led to its replacement of other hominids … we must examine how humans acquired the adaptive tendency to rapidly seek out cooperative solutions." Here we briefly discuss the cooperative foraging behaviors of the Ache and explore the idea that similar levels of cooperative food sharing among early humans may have contributed to their success by favoring generally cooperative traits. We follow Hill's lead and define cooperative foraging as any activity that "appeared mainly designed to raise the foraging return rate of another adult or unrelated child" (Hill 2002). This excludes some synchronous or mutualistic behaviors that have, in some cases, been considered as forms of cooperation in humans (Connor 1986). The kind of mutually beneficial behavior discussed by (Connor 1986) is interesting in its own right but poses less of an evolutionary puzzle than cooperative interactions in which the behavior is costly to one actor, at least in the short term. We also use a broad definition of foraging that includes collecting food through hunting for meat or gathering other plant and animal materials such as palms, honey, grubs or medicinal plants.

Before outside contact, the Ache generally lived in small groups of between 15 and 60 individuals with a fluid fission-fusion structure in which groups would break apart to forage and reconvene to share the proceeds of their foraging trips (Hill 2002). There is a tight social network between all Ache adults, even from different groups. It is estimated that, on average, the Ache spend about 10 % of all foraging time engaged in cooperative behaviors, and that in any one foraging session they may spend up to 50 % of their time cooperating (Hill 2002).

The most time-consuming type of cooperative food gathering is pursuit of small game, which is typically shared within Ache society. Hill (2002) proposes that this type of cooperative hunting was likely a precursor to other human cooperative tendencies and may have contributed to the evolution of widespread cooperation in the human lineage. Previous models have shown that food sharing may be more effective than diet change in preventing energetic shortfalls (Winterhalder 1986), and to the extent that food sharing represented an innovation in the human lineage, it could have contributed to the success of modern humans over other hominids by reducing dietary risk. Evidence from the archeological record suggests that although there may have been some food sharing in home bases as early as 400 kya, the process of cooperative hunting and meat sharing became more sophisticated in the Upper Paleolithic (Stiner et al. 2009).

Here we study a model of cultural niche construction, similar to that proposed by Creanza et al. (2012), which depicts the interaction between cooperative hunting and food sharing while incorporating the effects of assortative mating (or other homophily) and natural selection. We examine the possibility that the presence of cooperative hunting and food sharing could have led to fixation or persistence of cooperative traits in the human lineage that are reflected in the hunting activities of the Ache, and perhaps in the potential for strong reciprocity seen throughout human populations (Bowles and Gintis 2002; Henrich et al. 2001).

13.1.2 Tool Use and Teaching

The advent of the genus *Homo* coincides with the appearance of the first stone tools in the archeological record about 2.5 million years ago (Wood and Richmond 2000; Ambrose 2001). This technological breakthrough was accompanied by a flurry of biological and cultural evolutionary leaps. In a matter of a few hundred thousand years, stone tools evolved from rudimentary flint flakes and cores to tools that were sophisticated in both construction and use (Ambrose 2001). There was also a significant increase in brain size, geographical range and population size in members of the *Homo* genus (Ambrose 2001).The benefits of tool use were certainly high, and it is possible that the human lineage entered a positive feedback system of cultural niche construction and innovation of a number of traits facilitated by this increased brain size. For example, it has been suggested that Oldowan technology including rudimentary sharp stone flakes and hammer stones along with an understanding of the mechanics involved in the production of these tools (demonstrated by a low error rate in production (Roche et al. 1999)) may have provided easier access to high quality food resources, increasing energy available to meet the metabolic demands of a larger brain. Similarly, the increased complexity of tools in the Upper Paleolithic, including bone and antler needles, buttons, and ornaments, may have represented an advantage in protection from cold climates for *Homo sapiens* over other species (Gilligan 2007; Churchill 2008; Ambrose 2001; Klein 2008). According to Klein (2008), "(the) Out of Africa (hypothesis) postulates that the Neanderthals were replaced because they could not compete culturally with their modern human 'Cro-Magnon' successors," and we hypothesize that these cultural traits could have altered the selection pressures on, and transmission of, other cultural and genetic traits, thus further influencing the evolutionary dynamics in this period of transition.

Here we aim to investigate how cultural niche construction, through a number of cultural innovations along with an enhanced ability to spread these innovations, may have contributed to this success and shaped early human evolution. The relative ease with which members of our species could share information through high-fidelity learning mechanisms like teaching and imitation may have further increased the population-wide benefits of tool use and technology. Functional definitions of teaching (Caro and Hauser 1992) include stipulations that the behavior in the presence of a naive pupil must be costly. This condition is invoked in order to avoid the conclusion that teaching is present (especially in animal studies) when in fact the putative teacher's behavior serves a separate function. Although it is simpler to discern motives and intentions in human studies, here we include a cost to teaching in terms of time spent teaching in a trade-off with time spent raising offspring. In their two-gene model for the evolution of cultural transmission and reception (i.e. teaching and learning), Aoki and Feldman (1987) also included a fitness cost to an allele that allowed teaching. While some researchers have claimed that teaching is not ubiquitous in human societies (Whiten et al. 2003), this is usually taken to refer to directly spoken formal instruction and does not account for non-verbal instruction and more subtle forms of teaching such as pedagogical cueing (Csibra and Gergely 2011). For example, Hewlett and Cavalli-Sforza (1986) show that while the Aka Pygmies are not formally educated, they learn by observation combined with "instruction" through "the few things the educator did or said to transmit the skill or knowledge." The relative frequency of teaching and imitation in two groups of hunter-gatherers in the Congo Basin, the Aka and the Bofi, is discussed by Hewlett et al. (2011) who found that although teaching is relatively infrequent it is nonetheless present and constitutes an important contribution to social learning.

Although teaching in post-industrial societies is ritualized, formal, and in the vast majority of cases verbal, this may not be the case for teaching in many human societies. Nonetheless, teaching in some form seems to be present and much of this teaching is directed toward family and close kin. The adze stone tool knappers in Irian Jaya, Indonesia, restrict access to their highly structured stone tool apprenticeships to their sons or nephews (Stout 2002), Kpelle children in Liberia, while not explicitly taught, learn preferentially from their own parents due to near-constant spatial proximity (Lancy 1996), and Aka Pygmies in the Congo restrict their learning role models to parents, grandparents, or highly skilled others (Hewlett and Cavalli-Sforza 1986). These restrictions placed on costly teaching interactions hint at the importance of assortative interactions in the evolution of the cultural nature of teaching itself.

The evolution of different forms of social learning may also be critical to explaining the success of early modern humans. In their study of the social learning in populations of Congo Basin hunter-gatherers, Hewlett et al. (2011) suggested that although models of social learning with almost exclusively vertical transmission characterize early infant learning in these populations, neighboring farming populations engage in horizontal and oblique learning earlier and more frequently. We use models of the evolution of high fidelity information transmission (here characterized as "teaching") to elucidate and compare the effects of vertical and oblique learning on the spread of beneficial information through populations and discuss possible effects of these on the evolution of early humans. Here we use the term "vertical learning" to refer to a child learning from its parent and "oblique learning" to refer to a child learning from an individual in the parental generation that is not necessarily its parent. Our models extend the cultural niche construction model with assortment and selection recently proposed by Creanza et al. (2012).

13.2 Methods

13.2.1 The Basic Model

To investigate the possible role of culture (and particularly of teaching and cooperation) in the evolution of modern humans, we outline a cultural niche construction model that incorporates the effects of selection, homophily and cultural transmission. We consider a dichotomous vertically transmitted cultural trait, **T**, with alternative forms, *T* and *t*. Two other dichotomous, vertically transmitted cultural traits influence the evolution of **T**: **S**, a trait that determines the strength of selection on **T**, and **M**, a trait that determines the rate at which individuals preferentially mate or interact with those that share their **T** state.

There are, therefore, eight phenotypes: *TSM* (frequency denoted as x_1), *TSm* (x_2), *TsM* (x_3), *Tsm* (x_4), *tSM* (x_5), *tSm*

(x_6), *tsM* (x_7), and *tsm* (x_8). To simplify calculations, we assume that one sex only chooses a mate. We label the parent of this sex the "choosing parent". The form of the **M** trait (*M* or *m*) determines the probability of departure from random mating by the "choosing parent." The degree to which an individual of a given **T** state will preferentially mate with another individual of the same state is expressed by parameters α_i ($0 \le \alpha_i \le 1$), where $i=1$ corresponds to *M* and $i=2$ to *m*: a proportion $(1-\alpha_i)$ of *M* individuals choose mates randomly, and the remainder of the *M* individuals (α_1) choose to mate preferentially with individuals of the same **T** state; with corresponding definitions for *m* and α_2. The frequency of each type of mating pair is given in Table A.1.

The probabilities that each of the eight phenotypes are produced by each mating depend on the phenotypes of the parents (cultural or biological) and the transmission rates, b_i, c_i, and d_i for $i=\{0, 1, 2, 3\}$, which determine the probabilities of inheriting the various forms of **T**, **S** and **M** traits, respectively (all constant between 0 and 1), as shown in Table 13.1. To compute the frequency x_i of phenotype *i* in the next generation, each mating frequency is multiplied by the probability that the mating produces offspring of phenotype *i* and summed over each of the 64 possible mating combinations. Selection, specified by parameters that allow us to examine the special cases of cooperative hunting and teaching, operates after transmission and is described in the sections below. Equilibria are solutions of $x'_i = x_i$, for $i=\{1,2,3,\ldots,8\}$.

13.2.2 Cooperation Model

Here we consider the interaction between cooperative hunting and food sharing. In this formulation, the **T** trait refers to cooperative hunting of large or difficult prey items, with form *T* representing a strong propensity to cooperate in hunting while *t* individuals are unlikely to cooperatively hunt with others. This formulation of the model allows us to consider the capacity of individuals to assort based on their propensity to cooperate, as discussed by Apicella et al. (2012). We assume that the benefit of cooperative hunting increases with the proportion of cooperative individuals in the population such that the fitness of the cooperative hunting trait *T* is given by $1+\sigma_c \sum_{i=1}^{4} x_i$, where σ_c is a scaling factor and $\sum_{i=1}^{4} x_i$ is the frequency of *T* in the population. When the frequency of cooperative hunters in the population is close to 0, the fitness benefit of being a cooperative hunter also approaches 0. We then suppose the *S* form of the **S** trait represents the practice of food sharing after a hunt, a practice which is widespread in many modern hunter-gatherer bands but which may not have been as common or as sophisticated in Neanderthal or other early hominid populations (Stiner et al. 2009). Individuals of form *t* do not share and hence do not suffer the cost of such sharing. Both the sharing and cooperation trait are vertically transmitted, following observations by Hewlett et al. (2011) that such fundamental values are learned in early life in hunter-gatherer communities and are most likely vertically transmitted.

The selection pressure exerted on an individual is a function of both its **T** and **S** states. As mentioned, cooperative hunting increases the average yield (for example, of meat) and thus increases fitness by $\sigma_c \sum_{i=1}^{4} x_i$. However, sharing meat reduces a hunter's portion in the short term and so reduces fitness by σ_S. Thus, a *TS* individual will have fitness reflecting the benefit of cooperating and the cost of sharing any food he or she acquires: $1+\sigma_c \sum_{i=1}^{4} x_i (1-\sigma_s)$. *Ts* individuals are essentially defectors, reaping the benefits of cooperative hunting but failing to share food, and *Ts* individuals have fitness $1+\sigma_c \sum_{i=1}^{4} x_i$, gaining from cooperation but not suffering the cost of sharing. Similarly *tS* individuals suffer the cost of sharing but do not cooperatively hunt and have fitness $(1-\sigma_s)$. Finally, *ts* individuals will have a baseline fitness, normalized to 1 (see Table 13.2).

Table 13.1 Vertical transmission probabilities for **T**, **S** and **M**

	T	*t*		*S*	*s*		*M*	*m*
$T \times T$	b_3	$1-b_3$	$S \times S$	c_3	$1-c_3$	$M \times M$	d_3	$1-d_3$
$T \times t$	b_2	$1-b_2$	$S \times s$	c_2	$1-c_2$	$M \times m$	d_2	$1-d_2$
$t \times T$	b_1	$1-b_1$	$s \times S$	c_1	$1-c_1$	$m \times M$	d_1	$1-d_1$
$t \times t$	b_0	$1-b_0$	$s \times s$	c_0	$1-c_0$	$m \times m$	d_0	$1-d_0$

Table 13.2 Relative fitnesses of the eight possible phenotypes in the cooperative hunting model

Phenotype	Relative fitness
TS(*M*/*m*)	$1+\sigma_c \sum_{i=1}^{4} x_i (1-\sigma_s)$
Ts(*M*/*m*)	$1+\sigma_c \sum_{i=1}^{4} x_i$
tS(*M*/*m*)	$1-\sigma_s$
ts(*M*/*m*)	1

Table 13.3 Vertical transmission probabilities for **T** modified by **S**

	T	t		T	t
$TS \times T$	b_3	$1-b_3$	$Ts \times T$	b_3	$1-b_3$
$TS \times t$	$b_2(1+\gamma_1)$	$1-b_2(1+\gamma_1)$	$Ts \times t$	b_2	$1-b_2$
$tS \times T$	$b_1(1-\gamma_2)$	$1-b_1(1-\gamma_2)$	$ts \times T$	b_1	$1-b_1$
$tS \times t$	b_0	$1-b_0$	$ts \times t$	b_0	$1-b_0$

Much attention has been given to the evolution of cooperation in the context of relatedness or group structure (Hamilton 1964; Eshel and Cavalli-Sforza 1982; Traulsen and Nowak 2006; Nowak 2006). Although not strictly analogous, we can include the effect of mating homophily on the evolution of cooperative hunting through the assorting trait **M**, which controls the extent to which individuals choose to mate with those that share their **T** state as outlined in Sect. 13.2.1.

13.2.3 Teaching Model

13.2.3.1 Model 1: Teaching with Vertical Transmission

Here we describe a model of vertical transmission of the traits of teaching and tool use in the population. We assume that T represents preference for, or ability to use, one tool, and t represents a preference for, or ability to use, a different tool. In many of the analyses to follow, we assume the benefit of tool T (in terms of fitness) to be greater than that of tool t. We further assume that forms of the **S** trait represent ability to teach the use or construction of a tool to other individuals with S individuals able to teach and s unable to teach.

One parent, shown here as the first member of a mating pair in Table 13.1, will pass on his/her form of the trait in question (**T**, **S** or **M**) to the offspring of the respective matings according to the probabilities outlined in Table 13.1. In Table 13.3 the transmission probabilities, b_i, of individuals with S are modified so that the probabilities of passing on T or t are higher than for s individuals by $b_2\gamma_1$ and $b_1\gamma_2$, respectively.

After mating and transmission, the fitnesses of the individuals in the population are calculated according to their tool use behavior using $1+\sigma_T$ for T individuals and $1+\sigma_t$ for t individuals. Except where otherwise stated, σ_T and σ_t are normalized so that $\sigma_t = 0$.

13.2.3.2 Model 2: Teaching with Oblique Transmission

In model 1, the S trait increases the likelihood of vertically transmitting a **T** trait to an offspring through the parameter γ_1. In model 2, we allow vertical transmission of **T** to be controlled by the transmission parameters b_i alone. After vertical transmission, individuals learn obliquely through teaching. We include an extra step such that offspring with trait t can be converted to T by contact with individuals in the parental generation possessing that trait (TS individuals). The same holds for T offspring who contact tS teachers. Thus both T and t can be taught by contact with appropriate models. Darwinian fitness is calculated according to the fitness parameters after all transmission has occurred, as in the vertical model. Only S individuals can transmit a **T** trait in the oblique step. The oblique step is given by the equations:

$$x_1^o = x_1^v + \gamma_{o1} x_5^v \left(x_1^p + x_2^p\right) - \gamma_{o2} x_1^v (x_5^p + x_6^p)$$
$$x_2^o = x_2^v + \gamma_{o1} x_6^v \left(x_1^p + x_2^p\right) - \gamma_{o2} x_2^v (x_5^p + x_6^p)$$
$$x_3^o = x_3^v + \gamma_{o1} x_7^v \left(x_1^p + x_2^p\right) - \gamma_{o2} x_3^v (x_5^p + x_6^p)$$
$$x_4^o = x_4^v + \gamma_{o1} x_8^v \left(x_1^p + x_2^p\right) - \gamma_{o2} x_4^v (x_5^p + x_6^p)$$
$$x_5^o = x_5^v + \gamma_{o2} x_1^v \left(x_5^p + x_6^p\right) - \gamma_{o1} x_5^v (x_1^p + x_2^p)$$
$$x_6^o = x_6^v + \gamma_{o2} x_2^v \left(x_5^p + x_6^p\right) - \gamma_{o1} x_6^v (x_1^p + x_2^p)$$
$$x_7^o = x_7^v + \gamma_{o2} x_3^v \left(x_5^p + x_6^p\right) - \gamma_{o1} x_7^v (x_1^p + x_2^p)$$
$$x_8^o = x_8^v + \gamma_{o2} x_4^v \left(x_5^p + x_6^p\right) - \gamma_{o1} x_8^v (x_1^p + x_2^p)$$

Where x_i^v represents the frequency x_i after vertical transmission, x_i^o, the frequency after oblique transmission and x_i^p represents the frequency x_i in the parental generation. The efficacy of oblique teaching is given by the parameters γ_{oi}, which, for simplicity in some of our numerical analyses, are set equal for teaching both T and t ($\gamma_{o1} = \gamma_{o2}$). For both formulations in Sects. 13.2.3.1 and 13.2.3.2, we used numerical iteration to explore the dynamics of the evolutionary system across a wide range of parameter values. Finally, we introduce a cost to teaching in keeping with the more functional definitions of teaching often used outside anthropological sciences (Caro and Hauser 1992). As mentioned in the introduction, the cost to teachers was represented as a reduction in reproductive output that could correspond to the time invested in teaching. The frequencies of matings initiated by teachers (i.e. the choosing parent had the S phenotype) were altered by a factor of $1-\varepsilon$ such that a mating frequency $\mu_{i,j}$ as shown in Table A.1 becomes $(1-\varepsilon)\mu_{i,j}$ where i has the S phenotype. Here, ε represents a constant cost to teaching parents. In addition, we modeled a cost to teaching that was proportional to the teaching capacity of the parent. In this model, the cost was modified to reflect the fidelity of teaching, where the cost of teaching increases with its effectiveness (denoted by γ). In this case, $\varepsilon = q\gamma$, where q is a constant.

13.3 Results

13.3.1 Cooperation

We ran a set of simulations by sampling evenly from the parameter ranges given in Table C.1 (in Appendix C) and numerically iterating the cooperation model described in Sect. 13.2.2 using ~6.6 million separate parameter sets. For all tested parameter sets, one **T** trait, *T* or *t*, approached fixation, and which one fixed was determined by the transmission parameters, strength of selection and the strength of assortative mating.

Although there is a straightforward relationship between the two assortative mating parameters (Fig. 13.1a), the model suggests that assortative mating with respect to *T* (α_1) can decrease the fitness benefit to cooperative hunting (σ_c) required for *T* to fix (Fig. 13.1b). This result agrees with findings of previous theoretical work suggesting that high levels of assortative mating (and hence relatedness among cooperators) can allow cooperation to evolve more easily (Hamilton 1964).

With respect to the evolution of costly sharing, our results suggest that there is an intuitive relationship between the cost of sharing and the benefits of cooperation. For each set of parameter values, there is a value of the sharing cost (σ_s) that can balance the benefits of cooperation (σ_c) and allow the evolution of sharing *and* cooperation so that there is eventual fixation of the *TS* phenotype (Fig. 13.2a).

We see a similar tradeoff between costs and strength of transmission of the sharing trait *S* (Fig. 13.2b, c). This shows that accurate transmission of costly traits can balance negative selection allowing such cultural traits to fix despite quite strong Darwinian selection against them.

As illustrated in Fig. 13.1a, some parameter sets led to fixation of either *T* or *t* depending on the values of the homophily parameters, α_i. We examined all such parameter sets and observed that homophily is capable of dictating which cooperation trait approaches fixation when mixed matings of *T* and *t* are approximately equally likely to produce *T* and *t* offspring, that is, $b_1 + b_2$ is near 1. Similarly, we examined the parameter sets that could lead to fixation of either *T* or *t* depending on the benefits of cooperation and the costs of sharing and found a similar phenomenon. Thus, when the transmission of **T** does not strongly bias the fixation of *T* or *t*, homophily and selection jointly influence which trait is successful.

13.3.2 Teaching

High fidelity information transmission mechanisms such as teaching have previously been shown to increase average population fitness above that expected in a population of non-teachers (Fogarty et al. 2011). In the context of the possible role of these mechanisms in the replacement of Neanderthals by modern humans, it is also interesting to explore (1) whether or not the presence and fidelity of these teaching mechanisms (in this case represented by the parameters γ_i) can increase the rate at which a trait (for example the use of a new tool) approaches fixation, (2) whether the presence of these mechanisms can allow this trait to fix over a broader parameter range than would be the case in a population of non-teachers or non-imitators and (3) whether the channel of transmission (i.e. vertical or oblique) changes these relationships.

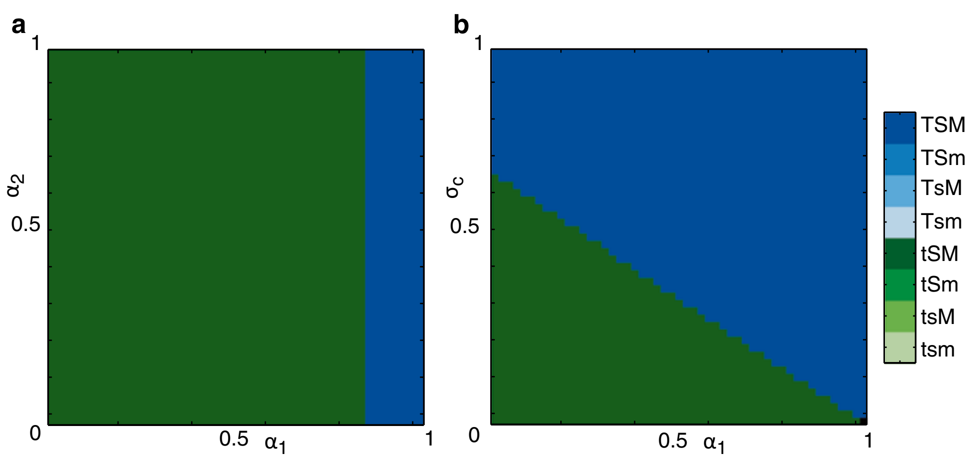


Fig. 13.1 The effects of assortative mating with respect to *T* (α_1) on fixation of the eight phenogenotypes (shown in the *colorbar*) against (**a**) assortative mating with respect to *t* (α_2) and (**b**) the baseline benefit of cooperation (σ_c). Other parameters are: $\alpha_2 = 0.15$, $b_0 = 0$, $b_1 = 0.49$, $b_2 = 0.48$, $b_3 = 1$, $c_0 = 0$, $c_1 = 0.85$, $c_2 = 0.59$, $c_3 = 1$, $d_0 = 0$, $d_1 = 0.74$, $d_2 = 0.7$, $d_3 = 1$, $\sigma_c = 0.1$, $\sigma_s = 0.09$, except where varied

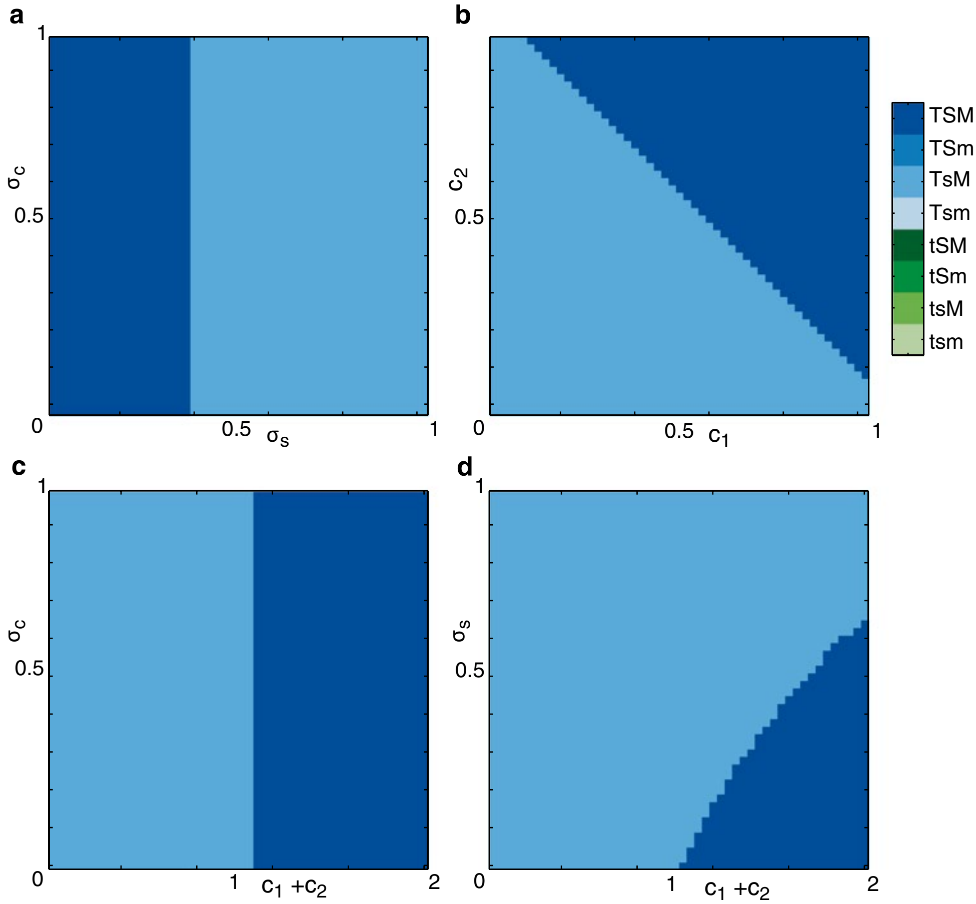


Fig. 13.2 (**a**) The effects of the costs of sharing (σ_s) on the fixation of the eight phenogenotypes (shown on *color bar*) against the baseline benefit of cooperation (σ_c). (**b**) The effect of the cultural transmission of costly sharing practices from mixed $s \times S$ matings (c_1) against transmission from $S \times s$ matings (c_2) on fixation of the phenogenotypes. (**c**) The effects of $c_1 + c_2$ on the fixation of S against the fitness cost of cooperating, σ_c. (**d**) The effects of $c_1 + c_2$ on the fixation of S against the fitness cost of sharing, σ_s. Other parameters are: $\alpha_1 = 0.12$, $\alpha_2 = 0.15$, $b_0 = 0$, $b_1 = 0.59$, $b_2 = 0.48$, $b_3 = 1$, $c_0 = 0$, $c_1 = 0.85$, $c_2 = 0.59$, $c_3 = 1$, $d_0 = 0$, $d_1 = 0.74$, $d_2 = 0.7$, $d_3 = 1$, $\sigma_c = 0.1$, $\sigma_s = 0.09$, except where varied

Of special interest here is the rate of evolution of the system and, in particular, the time to fixation of *S* (teaching) and *T* (the trait) in cases where they do approach fixation. It has been suggested that teaching, arguably a rare trait among non-human primates (Hoppitt et al. 2008), may accelerate the spread of cultural traits in populations, leading to potentially large group-level fitness benefits. Our models show that at low selective pressures (σ_T, $\sigma_t < 0.2$), the effect of γ_i in both vertical and oblique cases is to decrease the time to 95 % prevalence of *T* (tested parameter ranges given in Table C.2). This effect is more pronounced when teachers are present at high frequencies in the population, in the vertical case (Fig. 13.3a). In the oblique model, the relationship depends critically on the starting frequency of *T* and *S* in the population; in some cases, the relationship seen in the vertical model remains, but in other cases when the initial frequency of *tS* is high, the association between the less beneficial trait, *t*, and the teaching trait, *S*, entails that an increase in teaching can lead to an increase in the time it takes for *T* to fix in the population.

In the case of oblique teaching, we also see that an increase in strength or efficacy of teaching can allow the beneficial trait to fix in the population at lower fitness benefits to *T* (Fig. 13.3c). Thus, in the absence of teaching, the selective advantage would have to be greater to allow fixation of the beneficial trait. This relationship holds for both vertical and horizontal models, but is stronger where oblique transmission is possible (Fig. 13.3b, c).

The parameters controlling homophily also affect the likelihood of fixation of the trait *T*. In our numerical analyses, the effect of teaching is to decrease the strength of homophily needed to reach fixation of *T*. This effect is generally stronger in the oblique model (Fig. 13.4), and especially when the teaching parameter $\gamma = \gamma_1 = \gamma_2$ is very high (Fig. 13.4b).

The costs of vertical and oblique teaching were incorporated via the parameter ε, which was either a fixed cost applied to teaching or a proportional cost linked to the efficacy of teaching. The different forms of teaching cost could represent, respectively, a fixed cognitive cost to creating the neural architecture required to teach or, for

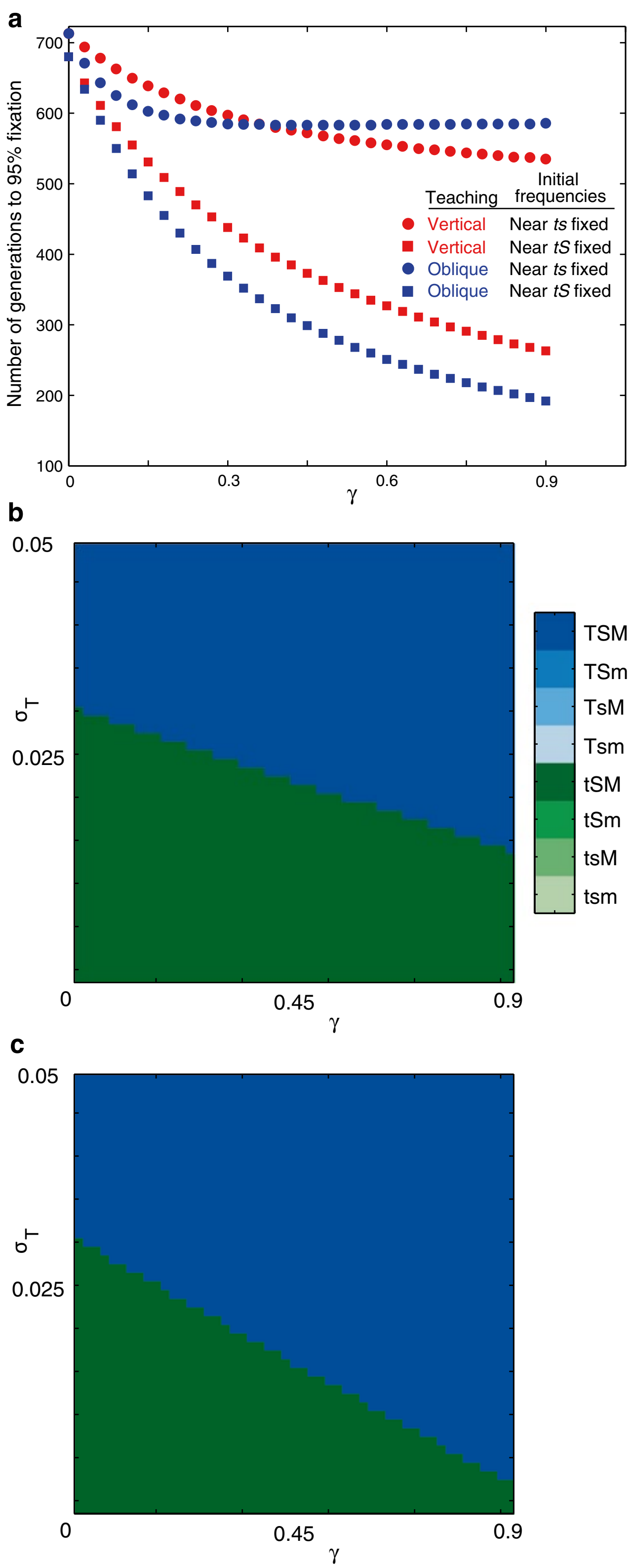


Fig. 13.3 The effect of teaching strength or efficacy on (**a**) time for the beneficial state T to reach 95 % fixation time (in generations) in the vertical and oblique models, (**b**) the range of σ_T values for which T can fix in the population in the vertical model, and (**c**) the range of σ_T values for which T can fix in the population in the oblique model. For all panels, the other parameters are: $\gamma_1=\gamma_2=\gamma$, $\alpha_1=0.84$, $\alpha_2=0.87$, $b_0=0$, $b_1=0.35$, $b_2=0.46$, $b_3=1$, $c_0=0$, $c_1=0.51$, $c_2=0.5$, $c_3=1$, $d_0=0$, $d_1=0.64$, $d_2=0.84$, $d_3=1$, $\sigma_T=0.04$, $\sigma_t=0$. In panel **a**, TS approaches fixation at all points illustrated, and T approaches fixation in fewer generations when the effect of teaching is stronger (greater γ). When T is introduced in a population where teaching is common (near fixation of tS), oblique teaching results in a faster increase of T in the population (*blue squares*). When T is introduced in a population where teaching is rare (near fixation of ts), oblique teaching results in a faster increase of T when teaching is weak (*blue circles*), and vertical teaching is faster when teaching is strong (*red circles*)

example, a time cost to teaching whereby more effective teaching requires a higher time investment. These distinctions were previously made by Fogarty et al. (2011) and represent a natural way to incorporate distinct facets of the costs of teaching. In the presence of a fixed cost, the effects previously discussed remain; teaching reduces both the level of assorting and the fitness benefit of a state required for that state to approach fixation. As shown in Fig. 13.5a, the strength of the effect and hence the slopes of the lines are different from those in Fig. 13.3a, reflecting the effect of the teaching cost parameter, ε. In addition, a high value of ε led to the fixation of s, eliminating teaching from the population. Similar results were found for the relationship between assorting and teaching to those for selection and teaching: a low value of ε led to a similar relationship between γ and α to that seen in Fig. 13.4, whereas a high value of ε led to the extinction of the teaching trait (S).

When the teaching costs depend on the value of γ, such that more effective teaching is more costly, a new pattern emerges (Fig. 13.6). Here we see that for low efficacy teaching ($\gamma<0.25$ and $\varepsilon=0.1\gamma$) a similar effect of γ to that of σ_T is observed, namely an increase in γ can decrease the selective advantage required for T to approach fixation. However, above this threshold (which is itself dependent on the value of ε), teaching cannot fix in the population, and the cases in which the beneficial trait T fixes are determined solely by the fitness benefit of T, σ_T, in both vertical and oblique teaching models (Fig. 13.6b, c).

Finally, we investigated whether the model presented above could lead to complex evolutionary dynamics such as internal polymorphic fixed points or oscillations as previously observed in similar models (Creanza and Feldman, *in review*) and under what circumstances we could expect to see these dynamics. In order to investigate the differences between the oblique and vertical models of teaching, we examined one parameter set that led to oscillations in both models (Fig. 13.7) and one parameter set that led to oscillations with vertical transmission but not with oblique transmission (Fig. 13.8). The former, which included a selective disadvantage to, but high transmission of, the T trait, led to oscillations for virtually identical parameter ranges in the

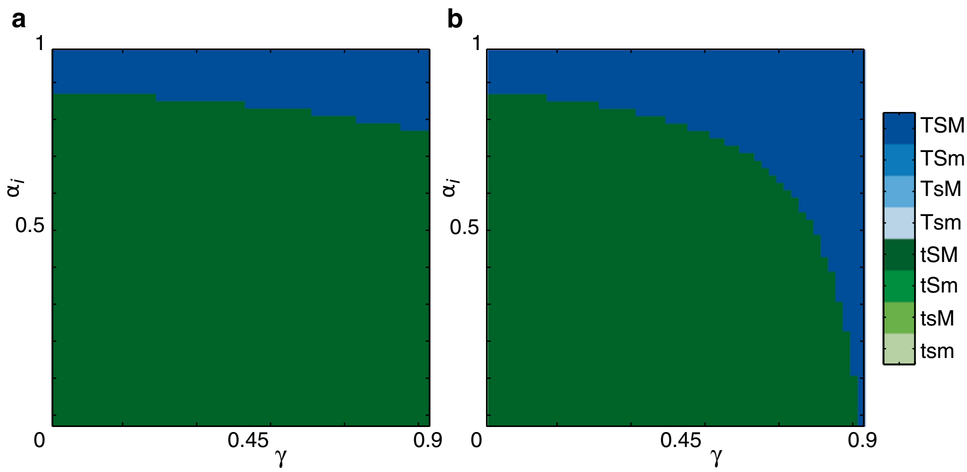


Fig. 13.4 The effect of homophily and teaching on the cultural evolution of the *T* trait in (**a**) the vertical learning model and (**b**) the oblique learning model. Other parameters are: $\alpha_1=\alpha_2$, $b_0=0$, $b_1=0.35$, $b_2=0.46$, $b_3=1$, $c_0=0$, $c_1=0.51$, $c_2=0.5$, $c_3=1$, $d_0=0$, $d_1=0.64$, $d_2=0.84$, $d_3=1$, $\sigma_T=0.04$, $\sigma_t=0$, $\gamma_1=\gamma_2=\gamma_{o1}=\gamma_{o2}=\gamma$

vertical and oblique models (Fig. 13.9a–d). The other parameter set, which included a selective advantage to, but low transmission of, the *T* trait, led to qualitatively different patterns in the emergence of complex evolutionary dynamics and fixation of various states (Fig. 13.9e–h).

13.4 Discussion

We have described a number of three-trait cultural niche construction models incorporating the effects of selection, assortative mating, and cultural transmission in order to investigate the possible role of niche construction in early human evolution. We focused particularly on the period of time in which our species coexisted with, and eventually replaced, earlier hominids and concentrated on two features that are uniquely well developed in modern humans: teaching and cooperation. The high fidelity (and costly) spread of beneficial information, along with cooperative tendencies that improve access to high energy foods while also stabilizing food supply across lifetimes, may have contributed to the success of early modern humans.

Hunter-gatherers were previously thought to learn horizontally from other children and obliquely from non-parents almost exclusively, with parents playing little or no role in learning (Harris 1998). By separating the learning in hunter-gatherer societies and small-scale farming societies, Hewlett et al. (2011) showed that vertical learning is the primary channel of cultural transmission for hunter-gatherers, whereas in farming communities the increased childcare responsibilities taken on by older children and other non-parents meant that horizontal and oblique learning became more important.

We investigated the cultural evolutionary consequences of a shift from teaching that increases vertical transmission of cultural traits to teaching that increases the oblique spread of traits to an offspring generation. Teaching of any kind (vertical *or* oblique) can allow cultural traits to fix more rapidly in a population but this effect is more pronounced and stronger when teaching is oblique (Fig. 13.3a). This raises the possibility that a transition from inadvertent social learning to deliberate teaching, along with a transition from purely vertical to oblique information transfer, may, in combination, have allowed early modern humans to spread useful knowledge more rapidly and with greater fidelity than previously possible. Similar effects are seen for costly teaching but with a threshold of cost above which teaching cannot invade. If the implementation of cost and the relationship between cost and efficacy of teaching modeled above is realistic, the results suggest that the optimal time dedicated to teaching a single trait would depend on the selective advantage of the trait and the difficulty of teaching it.

The model shows that traits can rapidly reach high frequencies in the population when teaching is present and oblique. Teaching reduces the fitness benefit required for a trait to fix in the population and this effect, too, is stronger when teaching is oblique. This implies that traits with smaller fitness increments can approach fixation in the population when teaching—especially oblique teaching—is present and may go some way towards explaining the highly developed cumulative culture that is unique to modern humans (Dean et al. 2012). Small improvements to technology, delivering small fitness rewards, could be expected to evolve in the presence of oblique teaching where they would fail to spread in a more rigid, and less efficient model of vertical inadvertent social learning or even vertical teaching (Fig. 13.3b, c).

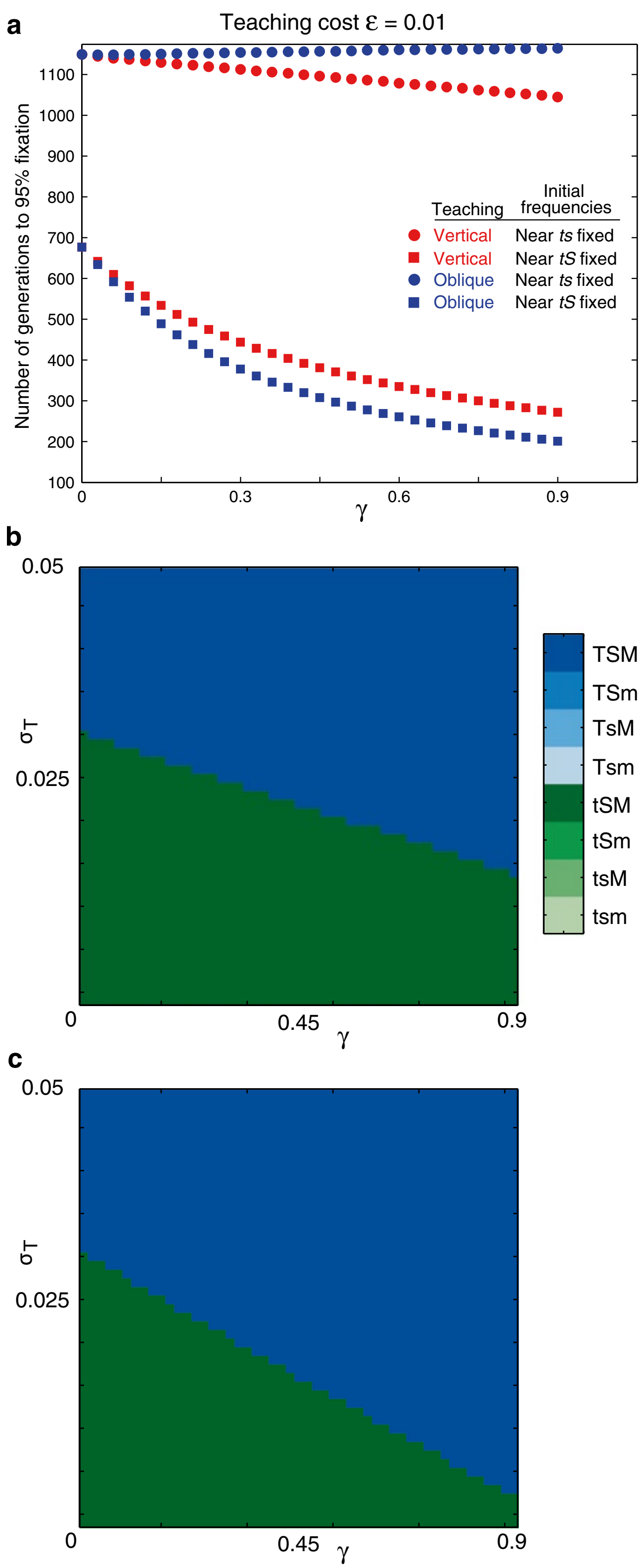


Fig. 13.5 The effect of teaching with a fixed cost ($\varepsilon = 0.01$) (**a**) time for the beneficial state T to reach 95 % fixation time (in generations) in the vertical and oblique models, (**b**) the range of σ_T values for which T can fix in the population in the vertical model, and (**c**) the range of σ_T values for which T can fix in the population in the oblique model. For all panels, the other parameters are: $\alpha_1 = 0.84$, $\alpha_2 = 0.87$, $b_0 = 0$, $b_1 = 0.35$, $b_2 = 0.46$, $b_3 = 1$, $c_0 = 0$, $c_1 = 0.51$, $c_2 = 0.5$, $c_3 = 1$, $d_0 = 0$, $d_1 = 0.64$, $d_2 = 0.84$, $d_3 = 1$, $\sigma_T = 0.04$, $\sigma_t = 0$ and $\gamma_1 = \gamma_2 = \gamma_{o1} = \gamma_{o2} = \gamma$. In panel **a**, *TS* approaches fixation at all points illustrated, and T approaches fixation in fewer generations when the effect of teaching is stronger (greater γ). When T is introduced in a population where teaching is common (near fixation of *tS*), oblique teaching results in a faster increase of T in the population (*blue squares*). When T is introduced in a population where teaching is rare (near fixation of *ts*), vertical teaching results in a faster increase of T (*red circles*)

It has been suggested that lithic technology remained effectively static from about 600 to 100 kya after which, about 50–40 kya, there was a period of accelerated technological improvement, (Klein 2008). While there are many plausible explanations for the boom, we suggest that the facilitation of cumulative culture by oblique or vertical teaching could have played a part.

Homophily has a similar effect on the cultural evolution of the T trait (here, the use of a beneficial tool) in the population, allowing T to evolve more easily with greater homophily. The level of assorting for which the focal trait (T) can evolve to fixation in the population is reduced with stronger teaching in both the vertical and oblique model, again with a stronger effect in the oblique model (Fig. 13.4a, b). For very high values of γ_i in the vertical model, relatively strong assorting is still necessary for the trait to evolve ($\alpha_i \leq 0.6$). In the oblique model, for very high γ_i, the trait can evolve even when members of the population mate randomly with respect to the trait in question. Again, this suggests that teaching could enable rare traits that have small fitness benefits and do not influence mating choices to persist in the population.

Teaching can also lead to complex evolutionary dynamics such as stable oscillations in trait frequencies (Figs. 13.7 and 13.8). This suggests that long term dynamics could maintain a number of competing traits in the population over time. As discussed in Creanza and Feldman (*in review*), these oscillations are driven by the interaction of cultural transmission, selection and assorting, can be approached from a number of starting conditions, and are stable over time. However, the oscillations do not appear to have an integer period and require further precise characterization.

We used the three trait cultural niche construction framework to investigate the cultural evolution of cooperative hunting tendencies and the propensity to share food with others in a cultural group. We investigated the evolution of general cooperative tendencies, via the interaction between two common types of cooperation that have a strong effect on fitness in human populations: cooperative hunting and food sharing. Although it has been suggested that food sharing is a beneficial trait that stabilizes food supply throughout a lifetime, we model food sharing as an immediately costly act. Conversely, we model cooperative hunting as a beneficial act that facilitates access to higher quality game than hunting alone, with the benefit of cooperative hunting increasing as more individuals engage in the practice. Although the marginal benefit

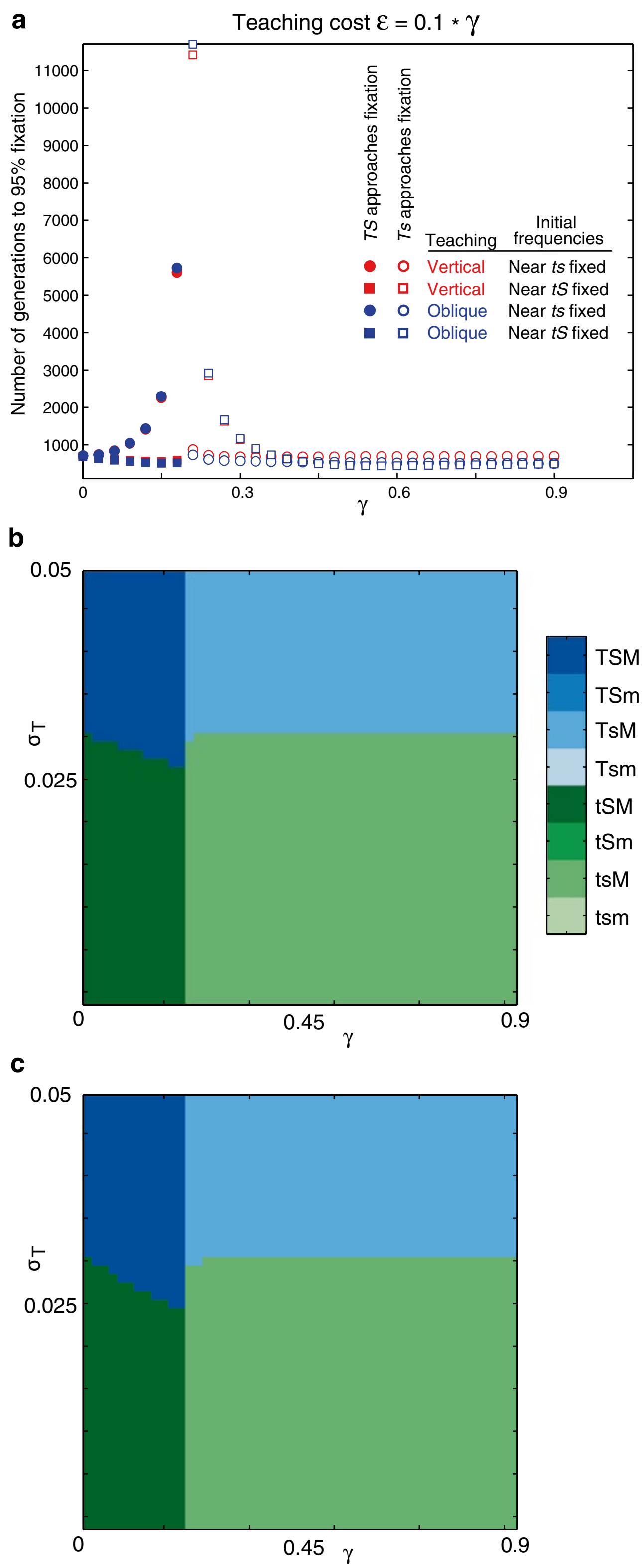


Fig. 13.6 The effect of teaching with a cost depending on the efficacy of teaching ($\varepsilon = q\gamma$) (**a**) time for the beneficial state T to reach 95 % fixation time (in generations) in the vertical and oblique models, (**b**) the range of σ_T values for which T can fix in the population in the vertical model, and (**c**) the range of σ_T values for which T can fix in the population in the oblique model. For all panels, the other parameters are: $\alpha_1 = 0.84$, $\alpha_2 = 0.87$, $b_0 = 0$, $b_1 = 0.35$, $b_2 = 0.46$, $b_3 = 1$, $c_0 = 0$, $c_1 = 0.51$, $c_2 = 0.5$, $c_3 = 1$, $d_0 = 0$, $d_1 = 0.64$, $d_2 = 0.84$, $d_3 = 1$, $q = 0.1$, $\sigma_T = 0.04$, $\sigma_t = 0$ and $\gamma_1 = \gamma_2 = \gamma_{o1} = \gamma_{o2} = \gamma$. In panel **a**, filled circles and squares indicate that *TS* approaches fixation and open circles and squares indicate that *Ts* approaches fixation. When γ is small, the teaching cost is low, and *TS* approaches fixation. Above a threshold level of γ, *tS* approaches fixation

due to additional cooperative hunters might decrease as they reach high frequency in the population, we make the simplifying assumption that the relationship is linear.

In our analysis, high rates of cultural transmission can allow the evolution of costly sharing and cooperative hunting even when the benefits of cooperative hunting are low and the costs of sharing are high (Fig. 13.2c, d) The role of strongly biased cultural transmission in the evolution of costly human behavioral traits has rarely been considered with models of the evolution of cooperation, which tend to focus instead on kin relationships and reciprocity (although see (Feldman et al. 1985)). Here we show that the effect of strong, high fidelity cultural transmission (through, for example, taboos or folk tales) can facilitate the evolution of strong cooperative tendencies, even when these are costly.

The effect of homophily is nonetheless important in the evolution of cooperative tendencies. Gurven et al. (2001) showed that much of the food sharing and reciprocal altruism seen in Ache societies living on reservations in Paraguay is between kin. The model presented here describes the effect of assortative mating among individuals who share a propensity to engage in cooperative acts. Although the "assortative mating" we discuss and the "assortative meeting" that Gurven et al. (2001) discussed are different, there are parallels and the cultural evolutionary outcomes are likely to be similar: when individuals mate preferentially with others that share their cooperative tendencies, cooperation can evolve with lower fitness benefits than would otherwise be possible.

The success of modern humans and their replacement of other early hominids has been attributed to a number of behavioral innovations accompanying the migration of modern humans out of Africa (Klein 2008). Here we show that these innovations (especially those offering small but potentially cumulative fitness benefits) could only have spread in a population capable of high fidelity information transmission and would have done so most effectively in populations in which individuals learned not just from their parents but from other knowledgeable individuals. We postulate that modern humans could have been uniquely equipped to spread useful innovations that had the potential to tip the balance in their favor in resource competition, especially if increased speed of dissemination of information allowed them to adapt more readily to changes in climate and food supply that likely accompanied large scale migrations.

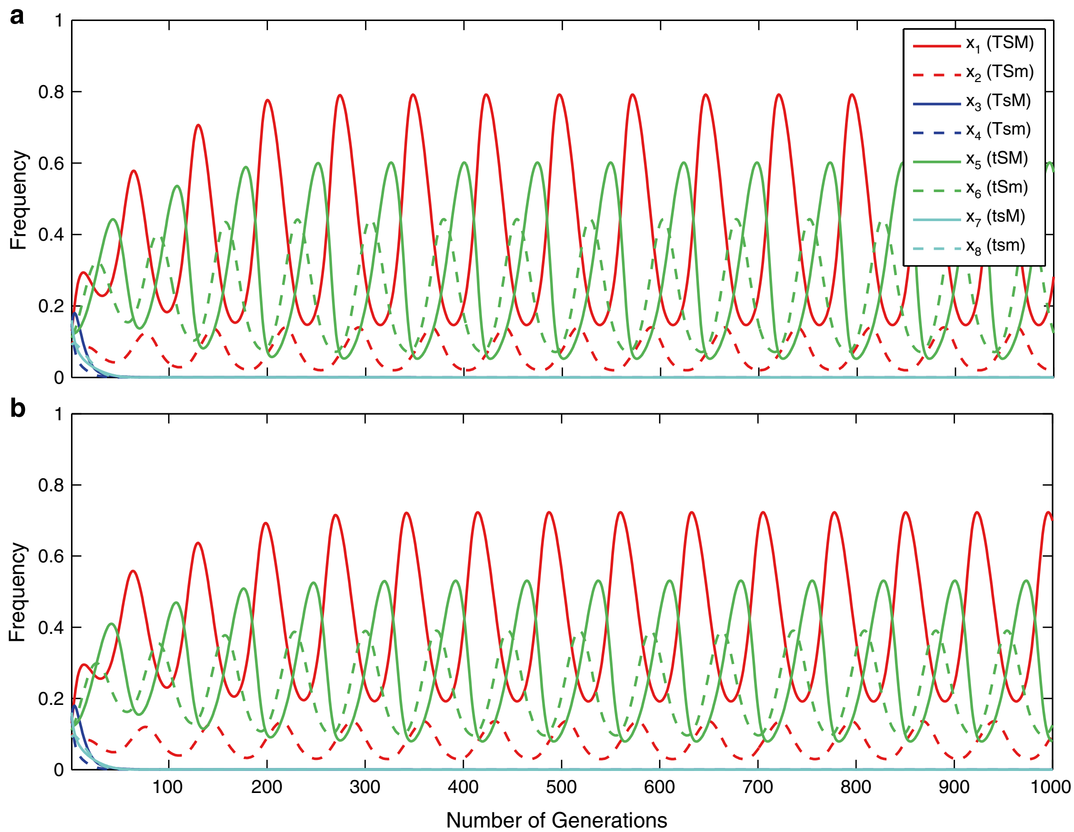


Fig. 13.7 Oscillations of four phenotypes in the model of teaching with specific levels of transmission, selection, and assorting. In this case, oscillations occur with both vertical and oblique teaching. Here, transmission of *T* is strong, *T* has a selective disadvantage, and teaching is weak. The parameters are: $\alpha_1=0.12$, $\alpha_2=0.75$, $b_0=0$, $b_1=0.85$, $b_2=0.88$, $b_3=1$, $c_0=0$, $c_1=0.43$, $c_2=0.67$, $c_3=1$, $d_0=0$, $d_1=0.29$, $d_2=0.86$, $d_3=1$, $\sigma_T=-0.33$, $\sigma_t=0$, $\gamma=0.01$ and $\gamma_1=\gamma_2=\gamma_{o1}=\gamma_{o2}=\gamma$. With both vertical teaching (**a**) and oblique teaching (**b**), *TSM, TSm, tSM*, and *tsm* persist, and their frequencies oscillate

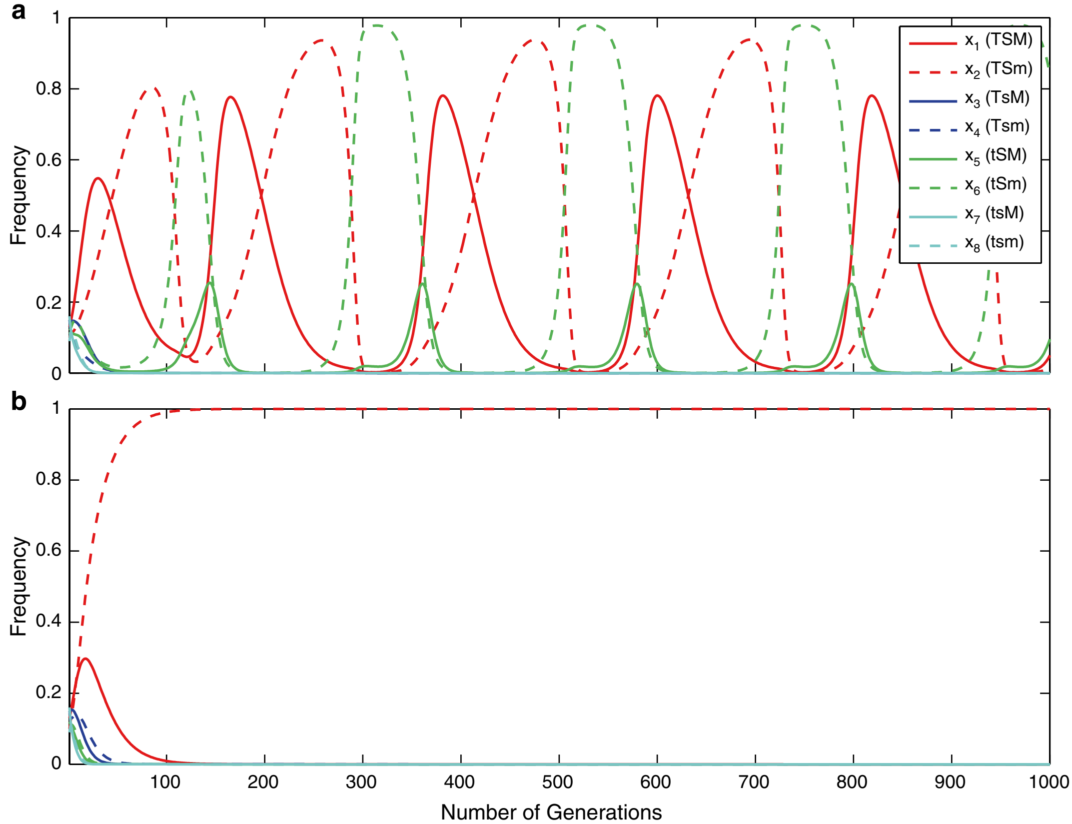


Fig. 13.8 Oscillations of four phenotypes in the model of teaching with certain levels of transmission, selection, and assorting. In this case, oscillations occur with vertical teaching but not oblique. Here, transmission of T is weak, T has a selective advantage, and teaching is strong. The parameters are: $\alpha_1=0.84$, $\alpha_2=0.15$, $b_0=0$, $b_1=0.15$, $b_2=0.18$, $b_3=1$, $c_0=0$, $c_1=0.33$, $c_2=0.77$, $c_3=1$, $d_0=0$, $d_1=0.39$, $d_2=0.56$, $d_3=1$, $\sigma_T=0.39$, $\sigma_t=0$, $\gamma=0.81$ and $\gamma_1=\gamma_2=\gamma_{o1}=\gamma_{o2}=\gamma$. (**a**) When teaching is vertical, the *TSM*,*TSm*,*tSM*, and *tsm* traits persist, and their frequencies oscillate. (**b**) When teaching is oblique, *TSm* approaches fixation

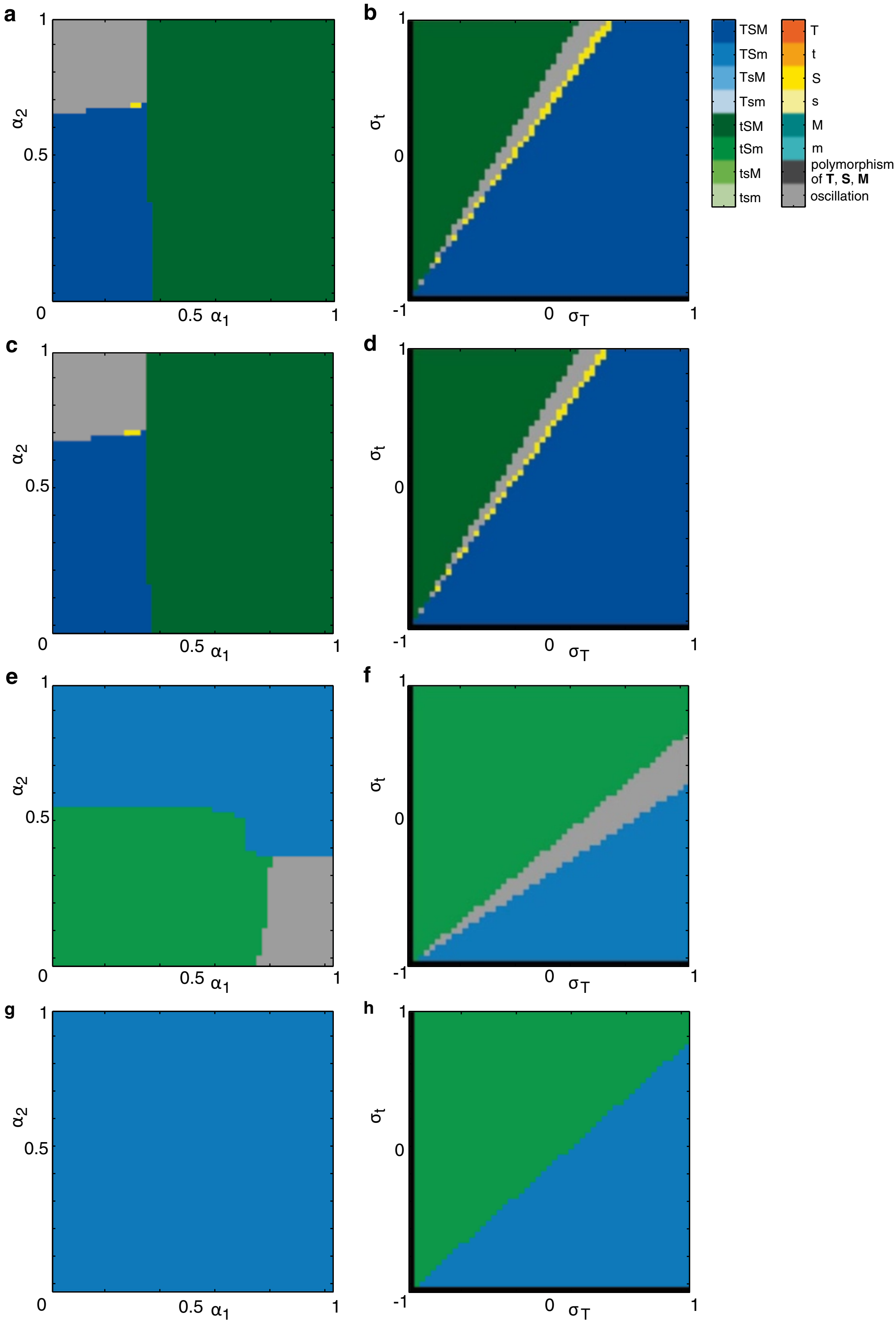


Fig. 13.9 The equilibria and oscillations approached with no cost to vertical or oblique teaching. Panels (**a**)–(**d**) are for parameters leading to complex dynamics in both vertical and oblique models. The level of assorting (α_i) is varied in the left panels and selection (σ_i) is varied in the right panels. Teaching is vertical in panels **a–b** and oblique in **c–d**. Vertical and oblique teaching lead to similar outcomes in this parameter space. For panels **a–d**, the other parameters are $\alpha_1=0.12$, $\alpha_2=0.75$, $b_0=0$, $b_1=0.85$, $b_2=0.88$, $b_3=1$, $c_0=0$, $c_1=0.43$, $c_2=0.67$, $c_3=1$, $d_0=0$, $d_1=0.29$, $d_2=0.86$, $d_3=1$, $\sigma_T=-0.33$, $\sigma_t=0$, $\gamma=0.01$ and $\gamma_1=\gamma_2=\gamma_{o1}=\gamma_{o2}=\gamma$. (unless varied). Results in panels **e–h** are for parameters giving complex dynamics with vertical teaching (**e–f**) but not with oblique teaching (**g–h**); oscillations (gray) are present only in panels **e–f**. For panels **e–h**, the other parameters are $\alpha_1=0.84$, $\alpha_2=0.15$, $b_0=0$, $b_1=0.15$, $b_2=0.18$, $b_3=1$, $c_0=0$, $c_1=0.33$, $c_2=0.77$, $c_3=1$, $d_0=0$, $d_1=0.39$, $d_2=0.56$, $d_3=1$, $\sigma_T=0.39$, $\sigma_t=0$, $\gamma=0.81$ and $\gamma_1=\gamma_2=\gamma_{o1}=\gamma_{o2}=\gamma$. (unless varied). When $\sigma_i=-1$, the system is undefined, illustrated in *black*

13.5 Appendix A: Mating Frequencies

Table A.1 Mating frequencies in three-trait cultural model

Mating	Frequency	Mating	Frequency
TSM×TSM	$\mu_{1,1}=(1-\alpha_1)x_1^2+\frac{\alpha_1 x_1^2}{x_1+x_2+x_3+x_4}$	*tSM×TSM*	$\mu_{5,1}=(1-\alpha_1)x_5x_1$
TSM×TSm	$\mu_{1,2}=(1-\alpha_1)x_1x_2+\frac{\alpha_1 x_1x_2}{x_1+x_2+x_3+x_4}$	*tSM×TSm*	$\mu_{5,2}=(1-\alpha_1)x_5x_2$
TSM×TsM	$\mu_{1,3}=(1-\alpha_1)x_1x_3+\frac{\alpha_1 x_1x_3}{x_1+x_2+x_3+x_4}$	*tSM×TsM*	$\mu_{5,3}=(1-\alpha_1)x_5x_3$
TSM×Tsm	$\mu_{1,4}=(1-\alpha_1)x_1x_4+\frac{\alpha_1 x_1x_4}{x_1+x_2+x_3+x_4}$	*tSM×Tsm*	$\mu_{5,4}=(1-\alpha_1)x_5x_4$
TSM×tSM	$\mu_{1,5}=(1-\alpha_1)x_1x_5$	*tSM×tSM*	$\mu_{5,5}=(1-\alpha_1)x_5^2+\frac{\alpha_1 x_5^2}{x_5+x_6+x_7+x_8}$
TSM×tSm	$\mu_{1,6}=(1-\alpha_1)x_1x_6$	*tSM×tSm*	$\mu_{5,6}=(1-\alpha_1)x_5x_6+\frac{\alpha_1 x_5x_6}{x_5+x_6+x_7+x_8}$
TSM×tsM	$\mu_{1,7}=(1-\alpha_1)x_1x_7$	*tSM×tsM*	$\mu_{5,7}=(1-\alpha_1)x_5x_7+\frac{\alpha_1 x_5x_7}{x_5+x_6+x_7+x_8}$
TSM×tsm	$\mu_{1,8}=(1-\alpha_1)x_1x_8$	*tSM×tsm*	$\mu_{5,8}=(1-\alpha_1)x_5x_8+\frac{\alpha_1 x_5x_8}{x_5+x_6+x_7+x_8}$
TSm×TSM	$\mu_{2,1}=(1-\alpha_2)x_2x_1+\frac{\alpha_2 x_2x_1}{x_1+x_2+x_3+x_4}$	*tSm×TSM*	$\mu_{6,1}=(1-\alpha_2)x_6x_1$
TSm×TSm	$\mu_{2,2}=(1-\alpha_2)x_2{}^2+\frac{\alpha_2 x_2{}^2}{x_1+x_2+x_3+x_4}$	*tSm×TSm*	$\mu_{6,2}=(1-\alpha_2)x_6x_2$
TSm×TsM	$\mu_{2,3}=(1-\alpha_2)x_2x_3+\frac{\alpha_2 x_2x_3}{x_1+x_2+x_3+x_4}$	*tSm×TsM*	$\mu_{6,3}=(1-\alpha_2)x_6x_3$
TSm×Tsm	$\mu_{2,4}=(1-\alpha_2)x_2x_4+\frac{\alpha_2 x_2x_4}{x_1+x_2+x_3+x_4}$	*tSm×Tsm*	$\mu_{6,4}=(1-\alpha_2)x_6x_4$
TSm×tSM	$\mu_{2,5}=(1-\alpha_2)x_2x_5$	*tSm×tSM*	$\mu_{6,5}=(1-\alpha_2)x_6x_5+\frac{\alpha_2 x_6x_5}{x_5+x_6+x_7+x_8}$
TSm×tSm	$\mu_{2,6}=(1-\alpha_2)x_2x_6$	*tSm×tSm*	$\mu_{6,6}=(1-\alpha_2)x_6{}^2+\frac{\alpha_2 x_6{}^2}{x_5+x_6+x_7+x_8}$
TSm×tsM	$\mu_{2,7}=(1-\alpha_2)x_2x_7$	*tSm×tsM*	$\mu_{6,7}=(1-\alpha_2)x_6x_7+\frac{\alpha_2 x_6x_7}{x_5+x_6+x_7+x_8}$
TSm×tsm	$\mu_{2,8}=(1-\alpha_2)x_2x_8$	*tSm×tsm*	$\mu_{6,8}=(1-\alpha_2)x_6x_8+\frac{\alpha_2 x_6x_8}{x_5+x_6+x_7+x_8}$
TsM×TSM	$\mu_{3,1}=(1-\alpha_1)x_3x_1+\frac{\alpha_1 x_3x_1}{x_1+x_2+x_3+x_4}$	*tsM×TSM*	$\mu_{7,1}=(1-\alpha_1)x_7x_1$
TsM×TSm	$\mu_{3,2}=(1-\alpha_1)x_3x_2+\frac{\alpha_1 x_3x_2}{x_1+x_2+x_3+x_4}$	*tsM×TSm*	$\mu_{7,2}=(1-\alpha_1)x_7x_2$
TsM×TsM	$\mu_{3,3}=(1-\alpha_1)x_3{}^2+\frac{\alpha_1 x_3{}^2}{x_1+x_2+x_3+x_4}$	*tsM×TsM*	$\mu_{7,3}=(1-\alpha_1)x_7x_3$
TsM×Tsm	$\mu_{3,4}=(1-\alpha_1)x_3x_4+\frac{\alpha_1 x_3x_4}{x_1+x_2+x_3+x_4}$	*tsM×Tsm*	$\mu_{7,4}=(1-\alpha_1)x_7x_4$
TsM×tSM	$\mu_{3,5}=(1-\alpha_1)x_3x_5$	*tsM×tSM*	$\mu_{7,5}=(1-\alpha_1)x_7x_5+\frac{\alpha_1 x_7x_5}{x_5+x_6+x_7+x_8}$
TsM×tSm	$\mu_{3,6}=(1-\alpha_1)x_3x_6$	*tsM×tSm*	$\mu_{7,6}=(1-\alpha_1)x_7x_6+\frac{\alpha_1 x_7x_6}{x_5+x_6+x_7+x_8}$

(continued)

Table A.1 (continued)

Mating	Frequency	Mating	Frequency
$TsM \times tsM$	$\mu_{3,7}=(1-\alpha_1)x_3x_7$	$tsM \times tsM$	$\mu_{7,7}=(1-\alpha_1)x_7^2+\frac{\alpha_1 x_7^2}{x_5+x_6+x_7+x_8}$
$TsM \times tsm$	$\mu_{3,8}=(1-\alpha_1)x_3x_8$	$tsM \times tsm$	$\mu_{7,8}=(1-\alpha_1)x_7x_8+\frac{\alpha_1 x_7 x_8}{x_5+x_6+x_7+x_8}$
$Tsm \times TSM$	$\mu_{4,1}=(1-\alpha_2)x_4x_1+\frac{\alpha_2 x_4 x_1}{x_1+x_2+x_3+x_4}$	$tsm \times TSM$	$\mu_{8,1}=(1-\alpha_2)x_8x_1$
$Tsm \times TSm$	$\mu_{4,2}=(1-\alpha_2)x_4x_2+\frac{\alpha_2 x_4 x_2}{x_1+x_2+x_3+x_4}$	$tsm \times TSm$	$\mu_{8,2}=(1-\alpha_2)x_8x_2$
$Tsm \times TsM$	$\mu_{4,3}=(1-\alpha_2)x_4x_3+\frac{\alpha_2 x_4 x_3}{x_1+x_2+x_3+x_4}$	$tsm \times TsM$	$\mu_{8,3}=(1-\alpha_2)x_8x_3$
$Tsm \times Tsm$	$\mu_{4,4}=(1-\alpha_2)x_4^2+\frac{\alpha_2 x_4^2}{x_1+x_2+x_3+x_4}$	$tsm \times Tsm$	$\mu_{8,4}=(1-\alpha_2)x_8x_4$
$Tsm \times tSM$	$\mu_{4,5}=(1-\alpha_2)x_4x_5$	$tsm \times tSM$	$\mu_{8,5}=(1-\alpha_2)x_8x_5+\frac{\alpha_2 x_8 x_5}{x_5+x_6+x_7+x_8}$
$Tsm \times tSm$	$\mu_{4,6}=(1-\alpha_2)x_4x_6$	$tsm \times tSm$	$\mu_{8,6}=(1-\alpha_2)x_8x_6+\frac{\alpha_2 x_8 x_6}{x_5+x_6+x_7+x_8}$
$Tsm \times tsM$	$\mu_{4,7}=(1-\alpha_2)x_4x_7$	$tsm \times tsM$	$\mu_{8,7}=(1-\alpha_2)x_8x_7+\frac{\alpha_2 x_8 x_7}{x_5+x_6+x_7+x_8}$
$Tsm \times tsm$	$\mu_{4,8}=(1-\alpha_2)x_4x_8$	$tsm \times tsm$	$\mu_{8,8}=(1-\alpha_2)x_8^2+\frac{\alpha_2 x_8^2}{x_5+x_6+x_7+x_8}$

13.6 Appendix B: Sample Recursion

A recursion for any x_i is generated by multiplying each mating frequency (Table A.1) by the transmission probabilities of obtaining phenotype *i* from that mating (Table 1) then summing across all matings and finally multiplying that sum by the relative fitness of the phenotype (Tables 2 and B.1). The recursions are normalized by the population mean fitness, $\overline{w}$. An example is given for a recursion in x_1 (TSM phenotype).

Cooperation/sharing model:

$$\gamma_i = 0$$

$$1+\sigma_1 = \left(1+\sigma_c \sum_{i=1}^{4} x_i\right)\left(1-\sigma_s\right)$$

Vertical Teaching model:

$$\sigma_1 = \sigma_T$$

Recursion for x_1

$$x_1^o = x_1^v + \gamma_{o1} x_5^v \left(x_1^p + x_2^p\right) - \gamma_{o2} x_1^v (x_5^p + x_6^p)$$
$$x_2^o = x_2^v + \gamma_{o1} x_6^v \left(x_1^p + x_2^p\right) - \gamma_{o2} x_2^v (x_5^p + x_6^p)$$
$$x_3^o = x_3^v + \gamma_{o1} x_7^v \left(x_1^p + x_2^p\right) - \gamma_{o2} x_3^v (x_5^p + x_6^p)$$
$$x_4^o = x_4^v + \gamma_{o1} x_8^v \left(x_1^p + x_2^p\right) - \gamma_{o2} x_4^v (x_5^p + x_6^p)$$
$$x_5^o = x_5^v + \gamma_{o2} x_1^v \left(x_5^p + x_6^p\right) - \gamma_{o1} x_5^v (x_1^p + x_2^p)$$
$$x_6^o = x_6^v + \gamma_{o2} x_2^v \left(x_5^p + x_6^p\right) - \gamma_{o1} x_6^v (x_1^p + x_2^p)$$
$$x_7^o = x_7^v + \gamma_{o2} x_3^v \left(x_5^p + x_6^p\right) - \gamma_{o1} x_7^v (x_1^p + x_2^p)$$
$$x_8^o = x_8^v + \gamma_{o2} x_4^v \left(x_5^p + x_6^p\right) - \gamma_{o1} x_8^v (x_1^p + x_2^p)$$

Table B.1 Relative fitnesses of the eight possible phenotypes in the teaching model

Phenotype	Relative fitness
T(S/s)(M/m)	$1+\sigma_T$
t(S/s)(M/m)	$1+\sigma_t$

13.7 Appendix C: Important Parameter Ranges

Table C.1 Parameter ranges sampled for cooperation/sharing simulations

Parameter	Values sampled
σ_c, σ_s	0–0.9
α_i	0.1–0.9
b_i	0.1–0.9
c_i	0.1–0.9
d_i	0.1–0.9

Table C.2 Parameter ranges sampled for teaching simulations

Parameter	Values sampled
σ_T, σ_t	–0.9–0.9
α_i	0.1–0.9
b_i[a]	0.1–0.9
c_i	0.1–0.9
d_i	0.1–0.9
γ_i[a]	0–0.9

[a]Where $b_i(1+\gamma_i) \leq 1$

References

Ambrose SH (2001) Paleolithic technology and human evolution. Science 291:1748–1753

Aoki K (1986) A stochastic model of gene-culture coevolution suggested by the "culture historical hypothesis" for the evolution of adult lactose absorption in humans. Proc Natl Acad Sci U S A 83:2929–2933

Aoki K, Feldman M (1987) Toward a theory for the evolution of cultural communication: coevolution of signal transmission and reception. Proc Natl Acad Sci U S A 84:7164–7168

Apicella CL, Marlowe F, Fowler J, Christakis N (2012) Social networks and cooperation in hunter-gatherers. Nature 481:497–501

Bowles S, Gintis H (2002) The origins of human cooperation. In: Hammerstein P (ed) The genetic and cultural origins of cooperation. MIT Press, Cambridge, pp 1–17

Caro T, Hauser M (1992) Is there teaching in non-human animals? Quart Rev Biol 67:151–174

Churchill S (2008) Weapon technology, prey size selection, and hunting methods in modern hunter-gatherers: implications for hunting in the Palaeolithic and Mesolithic. Archeol Papers Am Anthropol Assoc 4(1):11–24

Connor R (1986) Pseudo-reciprocity: investing in mutualism. Anim Behav 34:1562–1566

Creanza N, Fogarty L, Feldman MW (2012) Models of cultural niche construction with selection and assortative mating. PLoS One 7(8):e42744

Csibra G, Gergely G (2011) Natural pedagogy as evolutionary adaptation. Philos Trans R Soc Lond B Biol Sci 366(1567):1149–1157

Dean LG, Kendal R, Schapiro SJ, Thierry B, Laland KN (2012) Identification of the social and cognitive processes underlying human cumulative culture. Science 335(6072):1114–1118

Durham WH (1991) Coevolution: genes, culture and human diversity. Stanford University Press, Palo Alto

Eshel I, Cavalli-Sforza L (1982) Assortment of encounters and evolution of cooperativeness. Proc Natl Acad Sci USA 79(4):1331–1335

Feldman M, Cavalli-Sforza L, Peck J (1985) Gene-culture coevolution: models for the evolution of altruism with cultural transmission. Proc Natl Acad Sci U S A 82:5814–5818

Feldman MW, Cavalli-Sforza LL (1989) On the theory of evolution under genetic and cultural transmission with application to the lactose absorption problem. pp. 145–173. In Feldman MW (Ed.) Mathematical Evolutionary Theory. Princeton University Press

Fogarty L, Strimling P, Laland KN (2011) The evolution of teaching. Evolution 65:2760–2770

Gilligan I (2007) Neanderthal extinction and modern human behaviour: the role of climate change and clothing. World Archeol 39(4): 499–514

Gurven M, Allen-Arave W, Hill K, Hurtado AM (2001) Reservation food sharing among the ache of paraguay. Hum Nat 12(4):273–297

Hamilton W (1964) The genetical evolution of social behaviour. J Theor Biol 7(1):1–16

Harris J (1998) The nurture assumption: why children turn out the way they do. Free, New York

Henrich J, Boyd R, Bowles S, Camerer C (2001) In search of homo economicus: behavioral experiments in 15 small-scale societies. Am Econ Rev 91(2):73–78

Hewlett B, Cavalli-Sforza L (1986) Cultural transmission among Aka pygmies. Am Anthropol 88(4):922–934

Hewlett BS, Fouts HN, Boyette AH, Hewlett BL (2011) Social learning among Congo Basin hunter-gatherers. Philos Trans R Soc Lond B Biol Sci 366(1567):1168–1178

Hill K (2002) Altruistic cooperation during foraging by the ache, and the evolved human predisposition to cooperate. Hum Nat 13(1):105–128

Hill K, Hurtado AM (1996) Ache life history: the ecology and demography of a foraging people. Aldine deGruyter, New York

Hoppitt WJE, Brown GR, Kendal R, Rendell LE, Thornton A, Webster MW, Laland KN (2008) Lessons from animal teaching. Trend Ecol Evol 23(9):486–493

Ihara Y, Feldman M (2004) Cultural niche construction and the evolution of small family size. Theor Popu Biol 65(1):105–111

Klein R (2008) Out of africa and the evolution of human behavior. Evol Anthropol 17:267–281

Kurland J, Beckerman S (1985) Optimal foraging and hominid evolution: labor and reciprocity. Am Anthropol 87:73–93

Kylafis G, Loreau M (2008) Ecological and evolutionary consequences of niche construction for its agent. Ecol Lett 11:1072–1081

Laland KN, Odling-Smee J, Feldman M (1996) On the evolutionary consequences of niche construction. J Evol Biol 9:293–316

Laland K, Odling-Smee J, Feldman MW (1999) Evolutionary consequences of niche construction and their implications for ecology. Proc Natl Acad Sci U S A 96:10242–10247

Laland KN, Odling-Smee J, Feldman MW (2000) Niche construction, biological evolution, and cultural change. Behav Brain Sci 23(1):131–146, discussion 146–75

Laland KN, Odling-Smee J, Myles S (2010) How culture shaped the human genome: bringing genetics and the human sciences together. Nat Rev Genet 11(2):137–148

Lancy D (1996) Playing on the motherground: cultural routines for children's development. Guildford, New York

Lewontin R (1983) Gene, organism, and environment. Cambridge University Press, Cambridge, pp 273–285

Nowak MA (2006) Five rules for the evolution of cooperation. Science 314(5805):1560–1563

Odling-Smee J, Laland KN, Feldman M (2003) Niche construction – the neglected process in evolution. Princeton University Press, Princeton

Roche H, Delagnes A, Brugal JP, Feibel C, Kibunjia M, Mourre V, Texier PJ (1999) Early hominid stone tool production and technical skill 2.34 myr ago in West Turkana, Kenya. Nature 399:57–60

Simoons F (1970) Primary adult lactose intolerance and the milking habit: a problem in biological and cultural interrelations ii. a culture historical hypothesis. Digest Dis Sci 15(8):695–710
Stiner MC, Barkai R, Gopher A (2009) Cooperative hunting and meat sharing 400–200 kya at Qesem Cave, Israel. Proc Natl Acad Sci U S A 106(32):13207–13212
Stout D (2002) Skill and cognition in stone tool production: an ethnographic case study from irian jaya. Curr Anthropol 43:693–722
Traulsen A, Nowak MA (2006) Evolution of cooperation by multilevel selection. Proc Natl Acad Sci U S A 103(29):10952–10955
Whiten A, Horner V, Marshall-Pescini S (2003) Cultural panthropology. Evol Anthropol Issues News Rev 2(2):92–105
Winterhalder B (1986) Diet choice, risk and food sharing in a stochastic environment. J Anthropol Archaeol 5(4):369–392
Wood B, Richmond BG (2000) Human evolution: taxonomy and paleobiology. J Anatomy 196:19–60

The Effects of Cross-Boundary Rituals on Cultural Innovation

14

Shiro Horiuchi and Sachiko Kubota

Abstract

To clarify the mechanisms of how modern humans built a continually evolving culture while replacing Neanderthals, this report focuses on cross-boundary rituals that are attended by members of different groups. Field research on present-day modern humans shows that cross-cultural rituals constitute opportunities for distinguished individuals of different groups to communicate together and for young men to enter into marriage with other group members. An agent-based model simulation predicts that all agents accumulate cultural traits if agents with many traits participate in cross-boundary rituals and agents migrate between groups frequently. The significance of these rituals should be re-examined in light of the replacement of Neanderthals by modern humans.

Keywords

Boundary • Inter-group relation • Replacement

14.1 Introduction

The project, "Replacement of the Neanderthals by Modern Humans," attempts to test the hypothesis that modern humans replaced Neanderthals because of the pronounced learning abilities of the former. This paper proposes a sociological argument for why modern humans may have been more culturally advanced. This approach presents an alternative to, or an extension of, the basic learning hypothesis.

The process underlying this replacement of Neanderthals by modern humans (hereafter, "the replacement") is evident in archaeological remains, particularly in Europe, where modern humans expanded and Neanderthals became extinct. The remains also suggest that modern humans established elaborate cultures that included stone tools, wall paintings, ornaments, and various instruments, which were rarely observed in Neanderthal remains (Mellars 1989; Hoffecker 2005). These findings suggest that modern humans in Europe replaced other human species, such as Neanderthals, with the help of their culture. Indeed, modern humans have developed an advanced culture due to their keen desire and marked ability to learn; by adopting individual and social learning strategies, as well as their mixed strategy, modern humans could have advanced their culture.

It is only through archaeological studies that we can understand the marked ability of modern humans to learn. This approach enables us to grasp how these learning abilities evolved, how they affected the cultural remains, and how modern humans made use of their culture to replace Neanderthals.

Many researchers have approached the hypotheses, high leaning abilities of modern humans caused the replacement, through the perspective of their own sub-disciplines within the broader domain of archaeology. The authors of this report, who study sociology (S.H.) and cultural anthropology

S. Horiuchi (✉)
Center of Education Innovation, Shibaura Institute of Technology, 307 Fukasaku, Minuma-ku, Saitama 337-8570, Japan
e-mail: horiuchi.shiro@gmail.com

S. Kubota
Department of Cultural-Interaction, Graduate School of Intercultural Studies, Kobe University, 1-1 Rokkodai, Nada-ku, Kobe 657-8501, Japan
e-mail: kubotas@people.kobe-u.ac.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_14, © Springer Japan 2013

(S.K.), may appear to have little of relevance to contribute to archaeological studies on the replacement. However, research on the behavior and society of present-day modern humans allows us to understand how modern humans advanced their culture with the help of their learning abilities.

Previous studies have shown several differences between the Neanderthals and modern humans with respect to learning abilities (Mithen 1996). We focus on the well-known studies showing that modern humans traded across longer distances than did Neanderthals (Bar-Yosef 2002) and assume that such long-distance trading was accompanied by rituals involving members of different groups. At these rituals, participants would have sung, danced, and feasted together to reduce tensions between members of different groups, as discussed by Conkey (1980). The rituals might also have allowed participants to share their materials as well as their knowledge and techniques. Participants in the rituals would have needed the highly developed working memory, since they would have had to tolerate the existence of outsiders with whom they shared few common interests or customs. High working memory should have helped modern humans to learn individually or socially from others. We refer to rituals in which members of different groups communicate with one another as "cross-boundary rituals" and contrast these with "within-boundary rituals" that are performed by members of the same group.

In this report, we test the hypothesis that cross-boundary rituals affected the development of the culture of modern humans. We assume that modern humans advanced their ability to manufacture stone tools as well as ornaments, wall paintings, and musical instruments through cross-boundary rituals. To test this hypothesis, we introduce case studies of residents of rural areas in Japan (see the second section) and Australian Aboriginal people (see the third section) to show how present-day modern humans performed cross-boundary rituals. We then introduce an agent-based model (ABM) simulation (see the fourth section). This simulation identifies the types of cross-boundary rituals that are required for cultural accumulation. The final section discusses how cross-boundary rituals affected the cultural accumulation of modern humans.

14.2 Field Work Study 1: Japanese *Kagura*

14.2.1 Social Survey

Traditional rituals, "spirit dances" or "*kagura*," continue to be performed in many rural areas of Japan. In *kagura*, participating local residents wear traditional clothes and masks and dance to celebrate local spirits. Other local residents support the dancers by preparing dance halls, supplying food, and attending performances as audience members. At *kagura*, dancers and audience members pray to the local spirits for success with regard to agriculture, health and protection from disease, prosperity for their descendants, and so on. They also experience *kagura* as entertainment in that it involves feasting, enjoying time together, and marriage or mating arrangements within and across areas. Now *kagura* groups, that include dancers and some local residents as supporters, perform *kagura* in each rural area.

The numbers of dancers and audience members involved in *kagura* have decreased, primarily due to depopulation and ageing in many rural areas of Japan. Even in Miyazaki prefecture, which is famous as the "country of *kagura*," the situation resembles that in other prefectures; few residents participate in *kagura* as either dancers or audience in many rural areas.

Recently, *kagura* has been used to attract tourists, and an increasing number of tourists now visit *kagura* performances as audience members. Thus, some *kagura* performances have become cross-boundary rituals, or venues for communication between local residents and tourists. Many dancers have welcomed the influx of tourists, and the number of dancers has recently increased, particularly in Takachiho-cho, whose *kagura* groups are famous among many Japanese individuals (Horiuchi 2012). However, not all *kagura* performances are cross-boundary rituals. Indeed, some are within-boundary rituals in that some *kagura* groups limit participation to local residents, and few tourists attend performances. Thus, to test the effects of cross-boundary rituals on present-day modern humans, we can compare *kagura* groups in terms of how they deal with tourists. Given that some *kagura* groups are about to disappear, which would obviate their ability to advance or continue the local culture by passing it on to future generations, we can evaluate the effects of cross-boundary rituals by examining the extent to which *kagura* groups are active.

One of the authors (S.H.) interviewed members of the boards of education in 17 local municipalities in Miyazaki prefecture to ascertain how *kagura* groups continue their tradition and deal with inviting tourists to their performances. He also requested the addresses of the leaders of *kagura* groups and, due to the cooperation of the boards of education, he was able to mail questionnaires to 155 leaders of *kagura* groups, 87 (55 %) of whom responded.

To compare *kagura* groups according to how they deal with tourists, the author asked about the composition of audiences and about whether these were composed primarily of local residents or tourists. Audiences for 48 groups were composed primarily of local residents, and those for 39 groups consisted primarily of tourists. This report regards *kagura* performed by the former groups as within-boundary rituals and *kagura* performed by the latter groups as cross-boundary rituals.

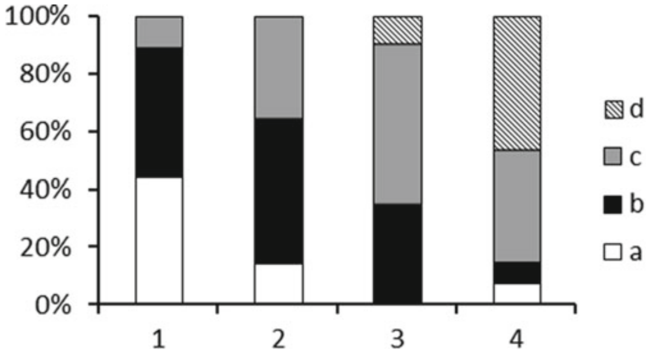


Fig. 14.1 The *x axes* represents *kagura* groups where the number of dancers increased (*1*), increased a bit (*2*), decreased a bit (*3*), and decreased (*4*). The *y axes* represents *kagura* groups where the number of audiences increased (*a*), increased a bit (*b*), decreased a bit (*c*), and decreased (*d*)

The author also asked whether the numbers of dancers and audience members had changed over the past 10 years. The data revealed a strong positive correlation between the two variables: increases in the number of dancers were associated with increases in the number of audience members and vice versa (Fig. 14.1; Chi-square test, df = 9, $P < 0.001$. Goodman–Kruskal Gamma = 0.68). Therefore, this report used principal component analysis for the two variables, which yielded one variable representing how the numbers of dancers and audience members changed during the past 10 years. This analysis classified the 87 *kagura* groups into two groups: 55 active groups, in which the numbers of dancers and audience members increased, and 32 non-active groups, in which the numbers of dancers and audience members decreased. The author compared active and non-active groups in terms of other variables. The average age of dancers had become younger during the past 10 years in active than in non-active groups (Chi-square test, df = 3, $P < 0.001$). Leaders of non-active *kagura* groups were more likely to close their *kagura* groups in the near future (Chi-square test, df = 2, $P < 0.01$) and to feel that their *kagura* groups had a shortage of dancers (Fisher's exact probability test, $P < 0.001$). Thus, the index, classification into active and non-active groups, may be a useful approach for measuring the activity level of *kagura* groups.

This report compared within-boundary and cross-boundary rituals with respect to activity level. However, the ratio of active to non-active groups did not significantly differ according to whether intra- or inter-group communication was involved (29/48 and 26/39, respectively, Fisher's exact probability test, $P > 0.1$). That is, *kagura* groups that invited tourists were not more likely to be either active or non-active.

The mechanisms by which *kagura* groups become active may differ with respect to within-boundary versus cross-boundary rituals. Indeed, the continuation of each type of ritual may require the exercise of different functions. To

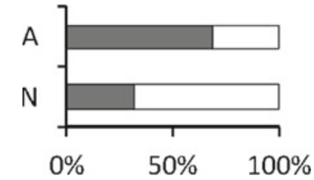


Fig. 14.2 The number of active groups (A) and non-active groups (N) of within-boundary rituals in which the leaders found communication with outsiders good (*white*) or not (*gray*)

identify the functions required for within-boundary and cross-boundary rituals, the author asked leaders to select which of 12 functions were used to perpetuate their *kagura*. Comparison of data from active and non-active groups may reveal the different mechanisms by which within-boundary and cross-boundary rituals persist. Hereafter, this report uses Fisher's exact probability test for analyses because all statistics involve one degree of freedom.

14.2.2 Results

The first author (S.H.) compared active and non-active *kagura* groups (29 and 19 groups, respectively) in terms of within-boundary rituals. The leaders of more groups (20/29) that were active, as compared to those that were not active (6/19) with respect to within-boundary rituals, reported poor communication with outsiders (Fig. 14.2, $P < 0.05$). He also compared active and non-active *kagura* groups in terms of cross-boundary rituals (26 and 13 groups, respectively). More leaders of groups that were active in this regard (24/26) than of those of groups that were not active in this regard (7/13) found communication with outsiders to be good (Fig. 14.3a, $P < 0.05$). More leaders of active (11/26) than of non-active (1/13) groups reported that *kagura* was a good way to advertise their local communities (Fig. 14.3b, $P < 0.05$). More leaders of active (13/26) than of non-active (2/13) groups reported that *kagura* presented opportunities to educate young dancers (Fig. 14.3c, $P < 0.05$). More leaders of active (21/26) than of non-active (6/13) groups experienced *kagura* as enjoyable (Fig. 14.3d, $P < 0.1$).

The results suggest that the strategies used by leaders and other members to activate their *kagura* should depend on whether the *kagura* performs within-boundary or cross-boundary rituals. When *kagura* is restricted to within-boundary rituals, members should limit participants to local residents and recruit from their communities. Indeed, many sociological studies have shown that fixed membership is a prerequisite to the development of trust within communities (Cohen 1985). Additionally, such an arrangement allows members to enjoy themselves without being watched by outsiders.

When *kagura* is performed as a cross-boundary ritual, members should communicate with tourists and advertise

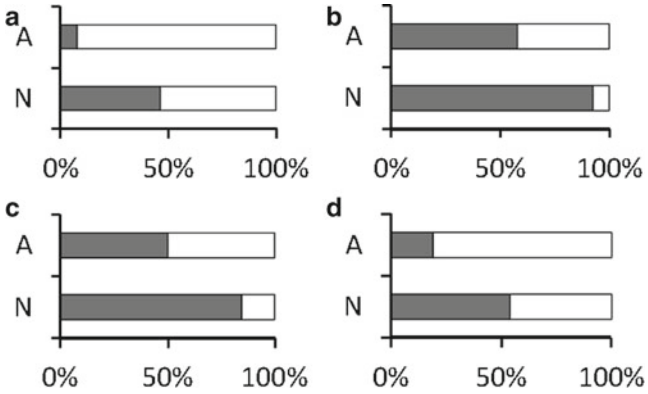


Fig. 14.3 The number of active groups (A) and non-active groups (N) of cross-boundary rituals in which (**a**) the leaders found communication with outsiders good (*white*) or not (*gray*), (**b**) the leaders found advertisement of their local communities to outsiders good (*white*) or not (*gray*), (**c**) the leaders found *kagura* as good opportunities for young dancers' education (*white*) or not (*gray*), (**d**) the leaders found *kagura* as fun (*white*) or not (*gray*)

their local communities. This would allow them to become known to tourists. In fact, some tourists have emotionally and financially supported *kagura* groups (Horiuchi 2012). Although members of open groups must tolerate the gaze of outsiders, as well as the attendant difficulties (Smith 1989), they also gain various resources from tourists.

Furthermore, leaders of *kagura* performing cross-boundary rituals found that they could educate young dancers and experience *kagura* as a form of enjoyment. The author interviewed dancers in some *kagura* groups who performed cross-boundary rituals. One dancer noted, "Some tourists have a highly developed sense of beauty. All the dancers in my group have trained themselves well to show our *kagura* to such tourists. Young dancers are particularly eager to train themselves." Another young dancer told him, "I'm very proud of our *kagura* group given that many tourists come all the way to this rural area to see our *kagura*. I work hard in all aspects of *kagura*; I do not want to be ashamed of mistakes. I want to be the leader of our *kagura* group in the future." Dancers, particularly young ones, who are watched by tourists gain experience as dancers. In fact, one male dancer married a female tourist, who had become fascinated with this dancer. Through *kagura*, young dancers will grow up to be highly accomplished members of their communities. Many dancers also reported that communication with tourists was enjoyable. Indeed, some tourists were distinguished artists; some were *kagura* dancers in other areas, painters or photographers of *kagura*, or researchers of *kagura*, and so on. The dancers add to the value of their *kagura* through the attendance of such distinguished tourists at their performances. These experiences let them find the fun in *kagura*, which may not be so accessible in within-boundary rituals.

Accordingly, cross-boundary rituals affect the cultural accumulation of contemporary modern humans by enlivening *kagura* through communication with outsiders. Cross-boundary rituals can include distinguished tourists, who then inspire the dancers to gain additional experience. Furthermore, some groups have started new *kagura* and have, coincidentally, attracted tourists; some have started new *kagura* with a view to intentionally attract tourists. Moreover, some dancers have advertised their *kagura* across wide areas (Horiuchi 2012). Dancers and tourists communicate with one another to advance their respective cultures. Such mechanisms were likely to be operating during the age in which the replacement occurred.

14.3 Case Study 2: Rituals in Aboriginal Society

14.3.1 The Place of Ritual Festivals in Yolngu Society

In northeastern Arnhem Land, in the Northern Territory, the Yolngu language speakers live in four villages established by Christian missionaries from 1923 to 1942. The villages have all modern facilities. Although there have been many changes to their way of life as a result of settling down, the Yolngu still value many of their traditional practices, especially their rituals. These rituals remain at the core of their social life and people devote considerable energy to them.

Aboriginal people are known to have lived in Australia for more than 50,000 years having arrived from Southeast Asia, and remained independent as hunter and gatherers until British colonization started in 1788. The Yolngu gave up an independent life between 1923 and 1946. In their traditional rituals, age segregation, clan affiliation and gender segregation are important. The second author (S.K.) will explore first how these rituals function, and their meaning in the Yolngu society.

When British colonization began, there were about 500 distinct language groups, of which Yolngu is one. The current national Aboriginal population is 548,000, with the Yolngu population numbering about 6,000. The Yolngu speakers are adjoined by other language groups, including the Nungubuyu, Rembaranga, Dangbon, Burarra, Nakara and Gunabidji. Despite the influence of Christianity and government policies, the Yolngu's traditional values are relatively strong. Traditional kinship relations, mythology, and rituals are still significant in everyday life. Their basic unit of social organization is the patrilineal clan. The clans are believed to have originated from the acts of mythological beings in the creation time. There are about 40 patrilineal clans in the Yolngu area, and each has a body of creation stories, songs and related sacred sites. They perform ritual festivals to celebrate the ancestral beings, which is participated by several different clans.

There are both public and restricted aspects to most rituals in the area, the restricted parts of rituals being for initiated men only. Women and children are excluded from the central part of the ritual. Each ritual has a different body of mythological content, some of which are regarded as sacred, and some are public. Funerals and initiation rituals are public, and all the men, women and children participate actively in them. In rituals, they sing and dance and paint designs on their bodies that represent the story of each ritual. Some clans share the same ancestral story because they have a common ancestral being who traveled through their clan countries creating the human population, and they perform the ritual together.

Education of the young is one of the important functions of the rituals (Butterworth 2003). Boys around 8–12 are circumcised and then they are gradually introduced into the more restricted rituals. Women and children are strictly excluded from the restricted part of the rituals and the associated knowledge. The knowledge includes songs, dances and paintings that relate to the ancestors' activities and the associated sacred sites. It is the senior male members of the clan who are the main custodians of this knowledge and the sites. It is their task to see that knowledge of the clan's rituals and stories are handed down to the younger generation before they themselves pass away. It is a common practice for senior men to hold an important restricted clan ritual if they find themselves becoming physically fragile.

Rituals are regarded as the occasion to renew the power of the ancestral beings. By singing and dancing the ancestral stories, they believe that the ancestral beings themselves got the power. They call it "taking care of the stories."

In addition/also, establishing social relationships is another important function of the rituals. People reaffirm the boundaries of each group by showing the differences in songs, dances, ritual ornaments, body paintings, and so on.

14.3.2 The Organization of the *Kunapipi* Ritual

Besides localized rituals, there are larger ritual festivals which not only bring members of many Yolngu clans but people from neighboring groups together. *Kunapipi* ritual, *Djunguwan* ritual, and *Ngarra* ritual are a few of those ritual festivals. As the second author mentioned earlier, some parts of them are sacred and secret (closed to women and children), and some are public. On these occasions people meet with members of other linguistic groups from distant places. They may exchange dances and songs which contribute to distantly related people making alliances and trade. Especially the *Kunapipi*, which is known as a big ritual festival that is attended by distant different groups and also is passed on to the neighboring groups, make a kind of alliance network. So it is known as a very important occasion for cultural exchange. Although songs and dances symbolize the core of their cultural knowledge are shared by the groups on these occasions, it is known that other cultural elements such as boomerangs and pearl shells were shared with groups from distant area on those occasions. As a result, pearl shells were traded into inland, and boomerangs were traded from inland to seashore area.

The Yolngu are famous for having a complex marriage system. The preferred marriage partner for a male is his mother's mother's brother's daughter's daughter (MMBDD), a second cross-cousin marriage. It means that you have to marry to a person from a particular clan group which is different from yours. Although it is not always the case in other areas, the Yolngu are known to prefer marriage between geographically and genealogically close kin (Harvey 2001). As a result, it was rare for Yolngu to make marriage arrangements during the rituals. Nevertheless it is known that there was an opportunity for wife exchange in some ceremonies like *Kunapipi* where visitors came from far away. During the *Kunapipi* ceremony, participants may swap wives at the end of the ritual (Berndt 1951). The organizers of a *Kunapipi* ceremony would send a messenger informing other groups that they planned to hold a ceremony. The ritual is regarded as very important and dangerous, great care was taken to do it so that it was done in the correct way. The first thing people who came from distant groups did was to establish their kin relationship to each other. Usually, this was done through finding someone they both knew. Where the relationship was that of a classificatory brother, there was the possibility for wife swapping at the end of the ritual.

The intercourse in the ritual had to be carried out with the consent of the female partner, which was essential if it was not to cause conflict. Men intending to swap wives had to send presents via a messenger who was in a special relationship to the receiver. On the last day of the ritual, after the previous exchange of messages and gifts, the men got together at the camp site of the *Kunapipi* ceremony and sat in a circle, with women dancing in the distance, showing their willingness to accept intercourse by a feathered headband on their forehead. While women were dancing sometimes with erotic movements, they were given presents, and exchanged jokes with the men who would be their partners later in the night. It was an occasion of excitement and laughter (Berndt 1951). After the dancing, ceremonial partners would have ritual intercourse.

14.3.3 Current Role of the Religious Festival in Arnhem Land

Ritual festivals have functioned as an occasion for the exchange of cultural as well as the genetic elements between the distant groups. Currently in Arnhem Land, though, these old sexual practices have been abandoned.

However, even nowadays, *Kunapipi* rituals remain a focus of social life. In contemporary situations, the ritual festivals function not only as occasions for the transmission of traditional knowledge from old to young, but also as an important occasion for socializing and cross- boundary exchanges of cultural knowledge and elements with people from distant places. Although the old sexual practices have ceased to happen, it is still an important occasion for socializing of the people. As people camp and stay for a long time for *Kunapipi*, sometimes for over a month, it is often the case to have social exchanges that include lovers and possible marriage partners. In a way, new material culture such as cars and planes, and changes of people's norm concerning marriages accelerated the possibilities of marriage with people from distant places. As it is now often the case that people getting married outside of the strict marriage rules, it is more likely that people find their lovers on those occasions. And also, with modern facilities, more people can come by plane, boats and cars, it even increases the possibilities of inter-group marriages, which increases the exchange of the cultural elements as a result.

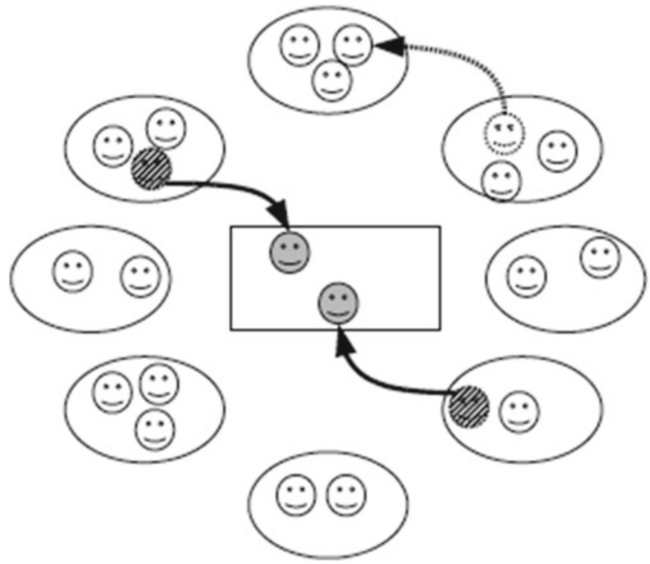


Fig. 14.4 The *solid arrows* represent cross-boundary ritual by two agents. The *dashed arrow* represents migration of an agent between groups

14.4 ABM Simulation

14.4.1 Computer Simulation

Following the Sects. 14.2 and 14.3, we assume that cross-boundary rituals affect cultural accumulation. Rituals enable participants to share knowledge between groups and may enhance cultural accumulation by integrating the knowledge of two groups. However, these rituals also pose the risk that new knowledge will be forgotten if the opponents do not respect the knowledge. Indeed, innovators may abandon new knowledge to follow the others, who remain ignorant of the new ideas. Organizations are necessary to preserve and disseminate new knowledge.

To test what types of rituals are necessary for cultural accumulation, this section introduces an ABM simulation. The ABM assumes n agents and m groups. The m groups are arranged along circular stepping-stones. n / m agents belong to each group at the initial condition, and the model assumes n to be a multiple value of m, so the number of members is the same integer value for all groups (Fig. 14.4).

Denote a number for each agent from 1 to n and for each group from 1 to m. Culture consists of k independent traits, represented as the vector $(c_{i,1}, c_{i,2}, \ldots, c_{i,k})$ for agent i. If the agent knows or does not know the jth cultural trait, $c_{i,j}$ is 1 or 0, respectively. Denote C_i as the total number of cultural traits that agent i knows, or $C_i = \sum_j c_{i,j}$. The range is $0 \le C_i \le k$ for any agent. At the initial condition, agents of group j know only the jth cultural trait, so $C_i = 1$ for all agents. Cultural trait j is the endemic knowledge of group j. The total number of groups equals the total number of cultural traits, or $m = k$, and the set of all groups is matched against the set of all cultural traits.

The simulation iterates turns composed of five steps, which represent innovation, loss, the within-boundary ritual, migration, and the cross-boundary ritual.

In the first step, selecting an agent $i1$ and a cultural trait $j1$ randomly, and the cultural trait $c_{i1,j1}$ becomes 1 by the probability p_1 and agent $i1$ innovates the cultural trait $j1$. In the second step, randomly selecting an agent $i2$ and a cultural trait $j2$, independent of the first step, and cultural trait $c_{i2,j2}$ becomes 0 by the probability p_2 and agent $i2$ loses the cultural trait $j2$. If $c_{i1,j1} = 1$ or $c_{i2,j2} = 0$ before each step, the traits do not change.

The third step represents the within-boundary ritual. Select an agent $i3a$ randomly. Also select another agent $i3b$ randomly from among agents that belong to the same group as agent $i3a$. Randomly select a cultural trait $j3$. Cultural trait $j3$ of agent $i3a$ becomes equivalent to that of agent $i3b$: $c_{i3a,j3}$ equals $c_{i3b,j3}$. Agents may learn or forget a cultural trait by this process of social learning, when opponents do or do not know the cultural trait. If the number of agents is only one in that group, the rituals do not happen.

In the fourth step, randomly select an agent $i4$. The agent moves from its residential group to one of two adjacent groups by probability x; the value x is an independent parameter in the model. This step represents the migration of agents between groups.

The fifth step represents the cross-boundary ritual. First, calculate the average value AC and the standard deviation DC of the number of cultural traits C_i of all agents. Each equals $\sum_i C_i / n$ and $\sqrt{[\sum_i (AC - C_i)^2 / n]}$, respectively. Then, calculate the *Z* score for the number of cultural traits of all agents. The *Z* score of agent *i*, or ZC_i, is $(C_i - AC) / DC$. Select two agents, *i5a* and *i5b*, whose *ZC* scores exceed *y*, which is an independent parameter in the model. Select a cultural trait *j5*. Cultural trait *j5* of agent *i5a* becomes equivalent to that of agent *i5b*: $c_{i5a,j5}$ equals $c_{i5b,j5}$. This procedure differs from the within-boundary rituals of step 3 since agents learn one another's cultural trait socially beyond the group boundary, and the value of *ZC* is relevant. As same as the third step, agents may learn or forget a cultural trait by this process, when opponents do or do not know the cultural trait.

We use the parameter *AC* as the cultural level of the general population. The purpose of this simulation is to investigate how swiftly the parameter *AC* increases as time passes. The value of *AC* should change by random processes as time passes, but the speed of the change should differ depending on the values of n, m, k, p_1, p_2, x, and y. The principal interest in this study is how migration and the cross-boundary ritual, or the values of *x* and *y*, respectively, affect the increasing speed of *AC*. When no cross-boundary rituals exist between agents, $y = \infty$.

14.4.2 Results

We set the independent parameters (n, m, k, p_1, p_2) as (200, 20, 20, 0.001, 0.01), respectively. We set the value of p_1 and p_2 be so small, since individuals usually try to follow their ascendants in ritual behaviors in the two field works (Sects. 14.3 and 14.4). We then changed the values of *x* and *y* to examine their effect on the value of *AC*.

When the value of *x* is 0 or 1, an agent never or always migrates between groups at each turn, respectively. When the value of *y* is ∞ or 1, the cross-boundary ritual is never held, or two agents whose *ZC*s are larger than 1 attend to the cross-boundary ritual, respectively. Figure 14.5 shows the average value of *AC* for 20 simulations along the value of *T* ($0 \leq T \leq 1{,}000{,}000$). When $x = 1$ and $y = 1$, the accumulative speed of *AC* is largest.

Since the model compare accumulative speed of cultural traits, we use T = 200,000 to compare the effects of *x* and *y*. Another set of simulations investigated the interactive effects of *x* and *y* on *AC* at $T = 200{,}000$. We compare the average values of *AC* for 20 simulations, setting the value of *x* as (0, 0.1, 1.0) and that of *y* as (−3.0, −2.0, −1.0, 0.0, 1.0, 2.0, 3.0, ∞), respectively. Figure 14.6 shows that *AC* becomes higher if the cross-boundary rituals are held between agents who have more cultural traits and agents move between groups, compared with cases of the cross-boundary rituals being held between mediocre agents or never, or when agents do not migrate between groups (two-way ANOVA: the effect of *x*, $P > 0.1$; the effect of *y*, $P < 0.001$; the interactive effect of *x* and *y*, $P < 0.005$).

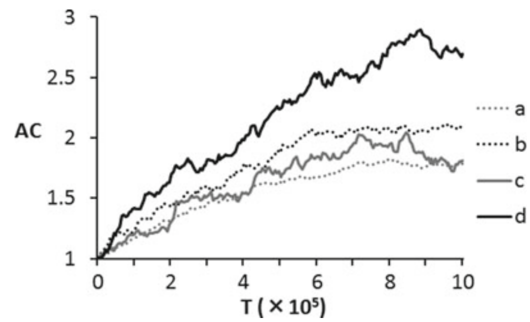


Fig. 14.5 The average value of AC for 20 trials over time (log scale). *a*: (x, y) = (0, ∞), *b*: (x, y) = (0, 1), *c*: (x, y) = (1, ∞), *d*: (x, y) = (1, 1)

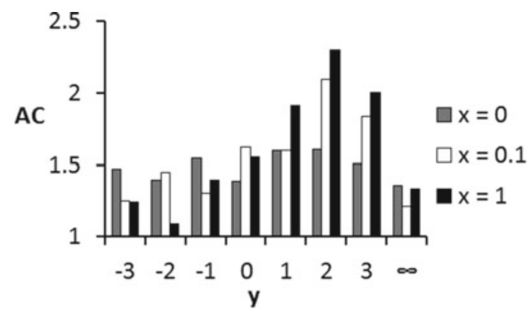


Fig. 14.6 The average value of AC for 20 trials at T = 200,000 for different values of (x, y)

The simulations suggest that agents swiftly accumulate their cultural traits if the cross-boundary rituals are held between agents who have a relatively greater number of cultural traits. Such cross-boundary rituals promote agents to swiftly accumulate their cultural traits. Agents also learn cultural traits within their group; the accumulated cultural traits prevail among all groups by the migration of agents. ABM studies explain these interactive effects of migration and the cross-boundary rituals on cultural accumulation. Here we may predict that the modern humans should have performed the cross-boundary rituals in which cultural elites, who have more cultural knowledge than average plausibly owing to high abilities to learn, or innovators, lead the communications. Furthermore, all the people should have migrated between groups to expand their advanced culture.

However, this model does not explain why modern humans performed cross-boundary rituals or migrated between groups. When modern humans began cross-boundary rituals and migration between groups, they would not have known they could advance their culture by doing so. Thus, cultural accumulation could not have been their original motivation. They should have started and continued cross-boundary rituals and migrations, for young individuals to be experienced and get married, as we introduced the cross-boundary rituals of present-day modern humans in Sects. 14.3 and 14.4.

14.5 Conclusion

In this paper we examined the fieldwork cases of Japanese and Australian cross-boundary rituals and presented the ABM simulation.

In the present cross-cultural rituals in Japan, local participants train themselves to be distinguished dancers when outside tourists visit their area, and more distinguished tourists then come to communicate with the dancers (second section). In Australia, Aboriginal rituals provide opportunities for inter-group cultural exchange and marriages (third section). The cross-boundary rituals have been a valuable opportunity for inter-group cultural exchange and marriages for a long time, and it may be one of the reasons why rural Japanese and Aboriginal people continue to have cross-boundary rituals. It surely functions as a means to connect members from different groups and accumulate cultural traits for the all. In the ABM simulation, it shows that if agents who have many cultural traits learn from one another at the cross-boundary rituals and agents migrate between groups at least once for ten turns, agents accumulate their cultural traits (fourth section). The reason is not clear why modern humans come long distances to perform the cross-boundary rituals, but the field study shows the importance of cross-boundary rituals.

However, the concept of "cross-boundary" is problematic here. When the cross-cultural interaction between local *kagura* performers and tourists from outside is described in the second section, it is between the geographically and socially different groups. But in the third section in Australia, cross boundary means between the different language groups which has clear geographical boundaries based on their mythology, and it has a slightly different application of the concept. But as a model, it supposes the different components of social groupings which can be commonly applied to both cases. And especially in the time of the replacement, it was quite probable that the different social groups meant distinct cultural groups.

Durkheim (1912) depicts the function of rituals as the intensification of a sense of solidarity of the group. But as we have seen, cross-boundary rituals are not attended only by the local population but are also attended by people from far away who do not interact on a frequent basis. The exchanges during the rituals opened up opportunities for knowledge exchange and marital exchange which are probably important sources of cultural innovation. They could also lead to intermarriage, migration and genetic exchange which increased the chances for stable cultural innovations.

In the cross-boundary rituals, people intend to gain a new culture from distant groups, and as a byproduct, the experienced dancers attract visitors and may gain a partner and advance their culture with newly claimed cultural elements. And with the accumulation of these repeated processes, at last the modern humans may have replaced the Neanderthals.

References

Bar-Yosef O (2002) The Upper Paleolithic revolution. Ann Rev Anthropol 31:363–393

Berndt R (1951) Kunapipi: a study of an Australian aboriginal religious cult. F.W. Cheshire, Melbourne

Butterworth D (2003) Learning earning Yolngu manhood: the process of Enskillment in an aboriginal Australian initiation ritual. Research Paper No. 11. School of Anthropology, Geography and Environmental Studies, The University of Melbourne, Melbourne

Cohen AP (1985) The symbolic construction of community. Tavistock Publications, London

Conkey MK (1980) The identification of prehistoric hunter-gatherer aggregation sites: the case of Altamira. Curr Anthropol 21:609–630

Durkheim É (1912) Les formes é lémentaires de la vie religieuse: le système totémique en Australie. Les Presses universitaires de France, Paris

Harvey M (2001) Oenpelli Kunwinjku kinship terminologies and marriage practices. Oceania 72:117–142

Hoffecker JF (2005) Innovation and technological knowledge in the Upper Paleolithic of northern Eurasia. Evol Anthropol 14:186–198

Horiuchi S (2012) Community creation by residents and tourists via Takachiko *kagura* in rural Japanese area. Sociol Mind 2:53–59

Mellars P (1989) Major issues in the emergence of modern humans. Curr Anthropol 30:349–385

Mithen S (1996) The prehistory of the mind. Thames and Hudson, London

Smith VL (ed) (1989) Hosts and guests: the anthropology of tourism, 2nd edn. University of Pennsylvania Press, Philadelphia

15

A Simulation Study on the Replacement of Neanderthals by Modern Humans in Europe: Implications of Climate Change, Cultural Diversification, and the Shape of the Continent

Yutaka Kobayashi

Abstract

The cause of the replacement of Neanderthals by modern humans is one of the biggest mysteries in human paleontology. Some emphasize the importance of climate change and others the role of competitive exclusion. In the present study, the following set of hypotheses, which invokes both of these factors, is proposed: (1) Modern humans spread into Europe 40 k years ago because they acquired techniques to live in treeless environments. (2) Among hominids only modern humans accomplished this because of distinct innovative abilities. (3) Climate change caused drastic increase of the rate of cultural evolution and cultural diversity. (4) Neanderthals survived in the Iberian Peninsula exceptionally long because the peninsula was a glacial refuge for trees. (5) Neanderthals rapidly disappeared in places other than the peninsula because modern humans inhibited their re-expansion in warm periods. A simulation model is constructed to show that the replacement possibly occurred in a way consistent with all the above hypotheses (1)–(5).

Keywords

Climate • Competitive exclusion • Culture • Learning • Model

15.1 Introduction

It is said that *Homo sapiens* appeared in Africa roughly 200 k years ago and replaced Neanderthals, who had been occupying Europe, roughly 40–30 k years ago (Klein 1999). The cause of the replacement is one of the biggest mysteries in human paleontology. Some argue that climate change or other external forces were the major cause of Neanderthals' extinction (Finlayson 2004; Finlayson and Carrion 2007), and others argue that competitive exclusion by modern humans played a significant role (Shea 2003; Banks et al. 2008; Hortola and Martinez-Navarro 2013).

Recently, Aoki and others have been suggesting innate difference in learning abilities between both species as a potential cause of the replacement and also the Upper Paleolithic revolution (e.g., Aoki and Nakahashi 2008; Kobayashi and Aoki 2012). They imagined that the direct cause of the Upper Paleolithic revolution was the distinct innovative ability of modern humans (the "learning hypothesis").

In contrast, Finlayson and others emphasize the role of climate change. They consider that climate change rather than neuronal revolution was the major cause of Neanderthals' extinction and also the drastic cultural shift. As far as inferred from the distribution of Mousterian, Neanderthals' habitats were consistently confined within woody areas (Finlayson 2004; Finlayson and Carrion 2007). They argue that Aurignacian

Y. Kobayashi (✉)
Organization for the Strategic Coordination of Research and Intellectual Property, School of Interdisciplinary Mathematical Sciences, Meiji University, 4-21-1 Nakano, Nakano-ku, Tokyo, 164-8525, Japan
e-mail: kyutaka@meiji.ac.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_15,

and later lithic industries consist of portable or projectile tools and therefore they were probably invented to explore treeless habitats.

Obviously, those hypotheses cannot directly be tested. However, good hypotheses must explain multiple (ideally all) observations without inconsistency. There are many unexplained observations regarding the replacement of Neanderthals by modern humans, and they can be used for indirect tests of hypotheses. It would be worth mentioning some important ones here. First, modern humans could not spread into Europe until 40 k years ago, although it appears that they were already out of Africa 100 k years ago (Shea 2003). What triggered the spread of modern humans into Europe? Second, modern humans' cultural complexity and diversity apparently exploded in the Upper Paleolithic, in which the replacement occurred. What caused the explosion and what is its implication for the replacement? Third, it appears that Neanderthals survived exceptionally long in the Iberian Peninsula (Zilhao 2000), but why?

In the present study, I take the position that climate change, inter-specific competition, and innate difference in learning abilities were all equally important. From this standpoint, I propose the following set of hypotheses regarding the replacement: (1) Modern humans spread into Europe because they acquired techniques to live in treeless environments (plains). Initially, the presence of Neanderthals in European forest inhibited modern humans from traveling north and reaching plains in the northern part of Europe. Therefore, selection pressure for plain-adapted techniques hardly operated, which is why it took some time for modern humans to explore plains. (2) Only modern humans accomplished this because they had distinct innovative abilities. (3) Climate change caused drastic increase of the rate of cultural evolution and cultural diversity. Evolutionary ecological theory predicts that genetic diversity can increase under environmental fluctuation. The same mechanism can enhance cultural diversity. (4) Neanderthals survived in the Iberian Peninsula exceptionally long because the peninsula was a glacial refuge for trees (Willis 1996). Importantly, modern humans were already adapted to plains. Therefore, they had trouble in exploring the refuge (or they were not attracted to it), which was occupied by last Neanderthals. (5) Neanderthals rapidly disappeared in places other than the peninsula because of consistent occupation by modern humans. Neanderthals were repeatedly evacuated from northern Europe along with the contraction of forest due to periodic temperature decline. However, they re-expanded in warm periods before modern humans were present. Modern humans probably inhibited this re-expansion by consistently occupying mid and northern parts of Europe.

Although each of the above hypotheses (1)–(5) sounds reasonable, it is unclear whether they are consistent with each other. In the present study, I construct a simulation model that takes climate change, inter-specific competition, and difference in innate learning abilities all into account. This model shows that the replacement of Neanderthals by modern humans can occur in a way consistent with all the above hypotheses (1)–(5). I am especially interested in the implications of climate change, cultural diversification, and the shape of the continent for the way the replacement occurs. This work is still in a preliminary stage and needs further improvement and extensive analyses. Nevertheless, preliminary results usefully suggest that multiple factors may have played significant roles in the replacement.

15.2 Methods

I consider a two-dimensional square lattice consisting of $80 \times 80 = 6{,}400$ cells. The cells of the lattice represent certain areas of the earth's surface and are categorized into water and land areas, where the latter are further categorized into forests and plains (Fig. 15.1). Here, "forests" and "plains" represent the areas with two different conditions in vegetation and fauna, and do not simply represent woody and treeless environments. For simplicity, I call vertical and horizontal coordinates latitudes and longitudes, respectively (latitude 0 and 79 correspond to the southernmost and northernmost cells, respectively). The vegetation state (forest/plain) of each land area stochastically changes with the course of time following a discrete-time Markov process independent of other areas. The transition probabilities between forests and plains in a cell depend on the temperature of the area in question, and for simplicity the temperature is assumed to depend on latitude and time but not on longitude. I assume that the one-step transition probability from a plain to a forest at latitude i is given by $\min\{1, a\exp[bT_i(t)]\}$, where a and b are positive constants and $T_i(t)$ is the temperature at latitude i at time t. Likewise, the one-step probability of the reverse transition is given by $\min\{1, a\exp[-bT_i(t)]\}$. Thus, high-temperature areas tend to become forests, while low-temperature areas tend to become plains. The temperature $T_i(t)$ may temporally fluctuate. For simplicity, I assume that the temperature varies cyclically, as follows:

$$T_i(t) = T_{i,0} + A\sin(2\pi t / L) \qquad (15.1)$$

where $T_{i,0}$ is the baseline temperature, A the amplitude of fluctuation, and L the period. The baseline temperature $T_{i,0}$ decreases linearly with latitude, implying that low- and high-latitude areas tend to become forests and plains, respectively. In this paper, I use $T_{i,0} = -0.5(i-40)$ so that the baseline temperature is zero at latitude 40 without loss of generality. If climate is stable ($A = 0$), the boundary (transitional region of vegetation) between forests and plains roughly stays at certain latitude (Fig. 15.1). On the other hand, if climate is variable ($A > 0$), the boundary periodically travels north and south.

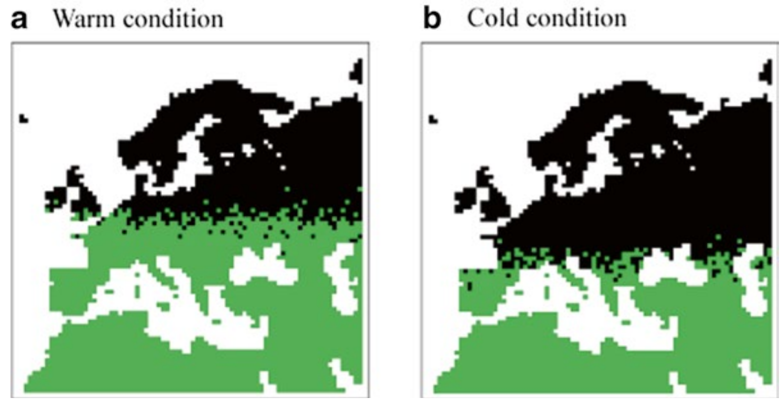


Fig. 15.1 The distribution of forest areas (*green*) in scenario 2 (stable and warm climate) (**a**) and that in scenario 3 (stable and cold climate) (**b**)

I consider population dynamics of two hypothetical species, namely Neanderthals and modern humans. I treat a band (group) of humans as the minimal unit of population and neglect further details in each band. Each land area can accommodate up to N human bands irrespective of species and vegetation types. Each band may have a finite number of distinct "techniques," which contribute to the survival of the band. These techniques may include for example skills to make tools for hunting or pieces of knowledge to exploit environment-specific resources. I assume that there are potentially n distinct forest-adapted techniques (techniques useful in forests) and likewise n distinct plain-adapted techniques (techniques useful in plains). Thus, each band may have at most $2n$ techniques, half of which are useful in forests and the other half in plains. A pair of n-dimensional binary vectors represents these collections of techniques. I call these vectors the forest-technology and plain-technology vectors. Each element of a technology vector represents the presence (1) or absence (0) of a certain technique.

In every time step, the following events take place in order: stochastic vegetation change, reproduction, death of some bands, and innovation and loss of techniques. In the vegetation change phase, the vegetation state of each land area changes according to the Markov process described above. In the reproduction phase, each band produces a daughter band with probability B. The mother band stays alive in the current position. The daughter band disperses to the native area with probability $1-m$ and to each of eight adjacent areas (i.e. Moore neighborhood) with probability $m/8$. Dispersal into a water area or a lattice boundary is rejected, so that bands trying to move to those areas are forced to disperse back to natal areas (i.e. reflecting boundary). The daughter band successfully settles with probability $1-x/N$, where x is the number of preexisting bands in the destination area. Bands reproduce in a random order to avoid spatial bias.

In the death stage, each band dies with a probability dependent on the local temperature and the technological state of the band. I assume that the death rate of a band of species S ("N" for Neanderthals or "M" for modern humans) in a land area in vegetation state V (forest or plains) at latitude i is given by

$$D_{i,S,V} = \min\left\{1,\ D_0 \exp\left[c_S\left(T_i-\tau\right)\right]\left(1-e\frac{k_V}{n}\right)\right\}, \qquad (15.2)$$

where D_0 is a positive constant, c_S the direct effect of temperature on death rate in species S, k_V the number of techniques adaptive in V, e the effect of technology on the survival rate, and τ the temperature at which both species have equal potential death rates. For simplicity, I assume $c_N=0$, so that Neanderthals are not directly affected by climate. On the other hand, I assume $c_M<0$, so that modern humans are more likely to die in cold areas. For example, in the setup of Fig. 15.2, the death rate of Neanderthals is fixed at 0.05 given that they do not have any useful techniques; on the other hand, the death rate of modern humans varies from 0.0462 to 0.0564 depending on temperature. Note that the death rate of modern humans is lower (higher) than that of Neanderthals when the temperature is higher (lower) than τ.

In the stage of innovation and loss of techniques, each band stochastically loses techniques. I suppose, for simplicity, that Neanderthals are so conservative that they never forget techniques. Likewise, modern humans never forget techniques that are currently in use. However, they may forget techniques that are currently not in use. That is, they may forget forest-adapted techniques in plains, and plain-adapted techniques in forests. I suppose that the rate of forgetting is given by a constant F. The loss of a technique is implemented by the change of an element of a technology vector from one to zero. For simplicity, I suppose that Neanderthals do not have innovation abilities. I assume that modern humans innovate useful techniques (e.g., forest-adapted techniques in forests) at rate I, but do never innovate useless techniques (e.g., plain-adapted techniques in forests). Acquirement of a technique is implemented by the change of an element of a technology vector from zero to one.

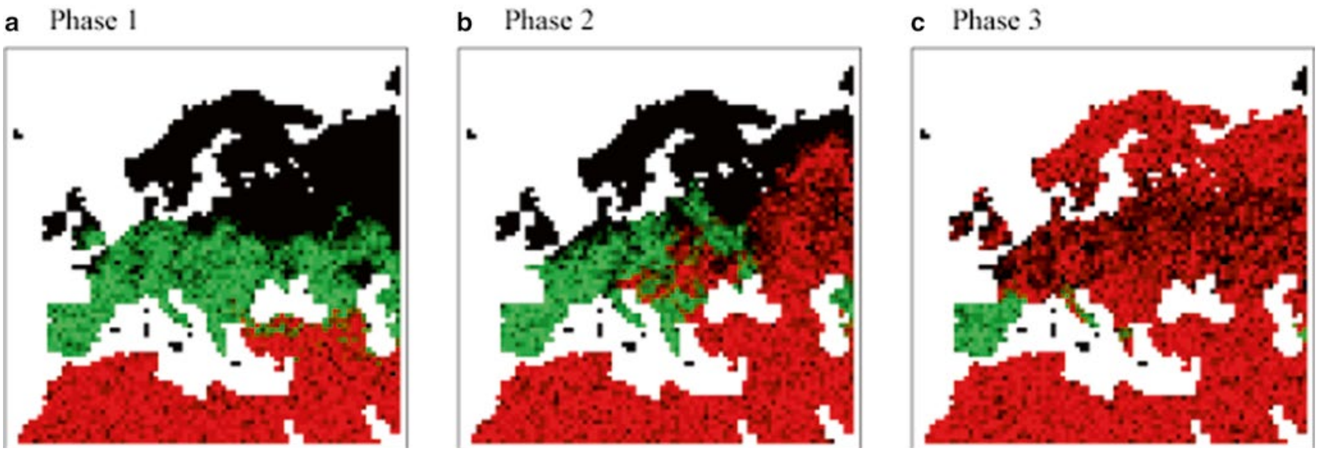


Fig. 15.2 Typical spatial distributions in phases 1 (**a**), 2 (**b**), and 3 (**c**) in the scenario with varying climate (scenario 1). $A=10.0$, $L=400$, $a=0.001$, $b=0.7$, $B=0.05$, $I=0.0004$, $F=0.003$, $D_0=0.05$, $e=0.8$, $m=0.7$, $c_M=-0.01$, $\tau=2.0$, $n=3$, $N=5$. *Red* and *green* represent areas where the densities of modern humans and Neanderthals, respectively, are high. *Black* and *white* cells are empty land areas and water areas, respectively

To simulate the replacement of Neanderthals by modern humans in Europe, the distribution of land areas in the lattice was generated using Mathematica ver. 8 from a real map of the world downloaded from the website of "Share the Global Map" Project (the URL is given in Acknowledgements). Neanderthals were initially distributed over land areas between latitude 31 and 40 (mid-latitude areas) with density 0.1, and modern humans between latitude 0 and 9 (low-latitude areas) with the same density. In the first 5,000 time steps the environment was kept stable ($A=0$) to eliminate effects of the initial density. The initial vegetation state of each land area was determined according to its equilibrium probabilities of being a forest and a plain. I assume that initially all bands of both species have all forest-adapted techniques, so that they are perfectly adapted to forest life.

To investigate the effects of varying climate and the importance of the shape of the European continent, I compare the following three scenarios. (1) In the first scenario, climate varies and the forest/plain boundary periodically travels north and south. The amplitude of temperature fluctuation is adjusted so that the southern limit of the boundary between forests and plains roughly corresponds to the northern edge of the Mediterranean and hence Mediterranean peninsulas remain covered with forest even when the climate is coldest (as in Fig. 15.1b). (2) In the second scenario, climate is stable and warm. Temperatures are the same as the baseline temperatures ($T_{i,0}$) of scenario 1 (Fig. 15.1a). (3) In the third scenario, climate is stable and cold. Temperatures are chosen so that the northern edge of forest corresponds to that of the Mediterranean (Fig. 15.1b). I chose rather extreme parameter values to exaggerate qualitative patterns of results, and therefore the parameter values are not based on data. Some of them are, however, supposedly not very far from the real. For example, given that floral turnover might possibly have occurred on the time scale of several hundred years and humans' generation time was probably roughly 20 years, at least choice of the values of L and B might not be extremely weird (see the caption of Fig. 15.3).

15.3 Results and Discussion

When climate varies (scenario 1), the replacement of Neanderthals by modern humans occurs in three phases (Figs. 15.2 and 15.3a). In the first phase, modern humans travel north very slowly (Fig. 15.2a). Since the distribution of modern humans is mostly confined within permanent forest areas, their population does not fluctuate much despite variable climate (Fig. 15.3a). Neanderthals, on the other hand, suffer from rapid vegetation change associated with climate change, and their population largely fluctuates (Fig. 15.3a). In the second phase, some of modern humans at the northern edge of their distribution, who occasionally experience loss of forests, acquire some plain-adapted techniques and successfully settle in northern plains (Fig. 15.2b). This causes a population explosion of modern humans in mid- and high-latitude areas (Fig. 15.3a). In mid-latitude areas, modern humans alternately acquire and lose forest- and plain-adapted techniques. Because loss and acquirement of techniques are stochastic, cultures in distant places develop more or less asynchronously. As a result, cultural diversity flourishes in the mid-latitude areas, where environments are highly variable (Fig. 15.4a). The spread of modern humans into the mid-latitude areas leads to rapid competitive exclusion of Neanderthals from those regions. Neanderthals are therefore eventually confined within small refuges, such as the Iberian Peninsula, Italian Peninsula, and Balkan Peninsula (Fig. 15.2c). In the third phase, Neanderthals

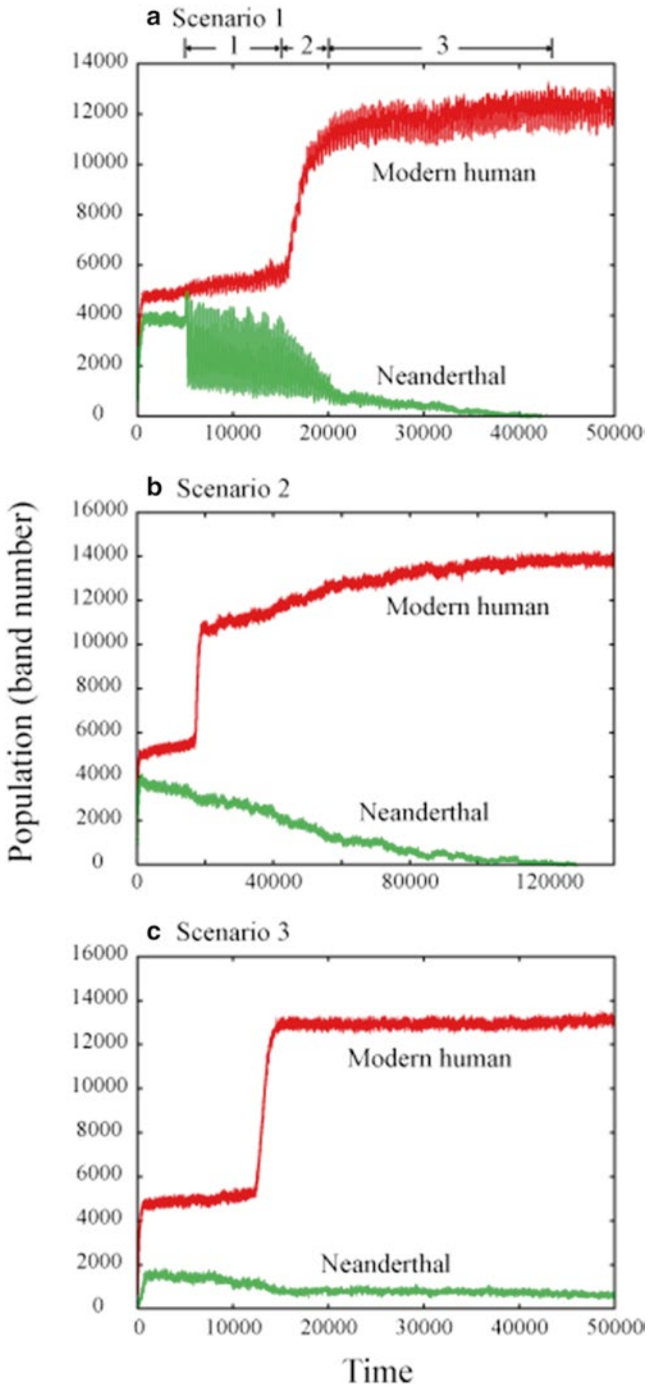


Fig. 15.3 Population dynamics of both species in scenario 1 (variable climate) (**a**), scenario 2 (stable and warm climate) (**b**), and scenario 3 (stable and cold climate) (**c**). In (**a**), parameter values are the same as in Fig. 15.2. In (**b**), parameter values are the same as in (**a**) except $A = 0$. The death rates of the two species are equal at latitude 36 under this setup. In (**c**), parameter values are the same as in (**b**) except the baseline temperatures ($T_{i,0}$) were declined by 5.0 at all latitudes. The death rates of the two species are equal at latitude 26 under this setup

remaining in the refuges are very slowly replaced by modern humans and finally go extinct (Fig. 15.3a).

The third phase typically lasts very long. This is explained as follows. The refuges, i.e., the Mediterranean peninsulas, are permanently covered with forests, and Neanderthals in those peninsulas are perfectly adapted to forest. On the other hand, the modern humans living near the entrances of the peninsulas, who occasionally experience loss of forest, are only partially adapted to forests, and therefore they can hardly break into the peninsulas occupied by Neanderthals. Even worse, the climate around the northern edges of the refuges is cold, and hence the viability of modern humans is relatively low. We found that the refuge of the Iberian Peninsula is especially stable and persistent compared to other refuges, so that modern humans tend to spend most of time in phase three to break into this refuge. The refuge of the Italian Peninsula was also found to be very persistent in some simulations. According to this result, it is highly likely that the last remains of Neanderthals are found in the Iberian Peninsula, and this seems indeed true (Zilhao 2000; Zilhao et al. 2010).

When climate is stable and warm (scenario 2), the replacement occurs, but in a quite different way than in scenario 1. Modern humans first gradually travel north and eventually spread into plains (Fig. 15.3b). However, the population explosion of modern humans does not affect the population dynamics of Neanderthals unlike in scenario 1. This is because Neanderthals are absent in plains anyway, and hence the spread of modern humans into plains causes no competitive exclusion. Neanderthals gradually decrease at a constant rate and finally go extinct (Fig. 15.3b).

In contrast, when climate is stable but cold (scenario 3), Neanderthals virtually permanently survive in the peninsulas and do not go extinct (Fig. 15.3c). This somewhat surprising result is explained as follows. In the setup of scenario 3, forests in the peninsulas are completely isolated from other forests. Therefore, modern humans can never reach the peninsulas before they spread into plains. However, once they spread into plains, they become perfectly adapted to plains and instead forget all forest-adapted techniques. Therefore, the modern humans who live near the entrances of the peninsulas are unviable in forest, while Neanderthals in the peninsulas are perfectly adapted to forest. This is why modern humans cannot break into the peninsulas. In contrast, in scenario 1, modern humans near the entrances of the peninsulas are partially adapted to forest life because forests periodically come back to those regions. Therefore, they have much higher chances to break into peninsulas than in scenario 3. In both scenarios 2 and 3, cultural diversity is consistently very poor in all regions unlike in scenario 1 (Fig. 15.4).

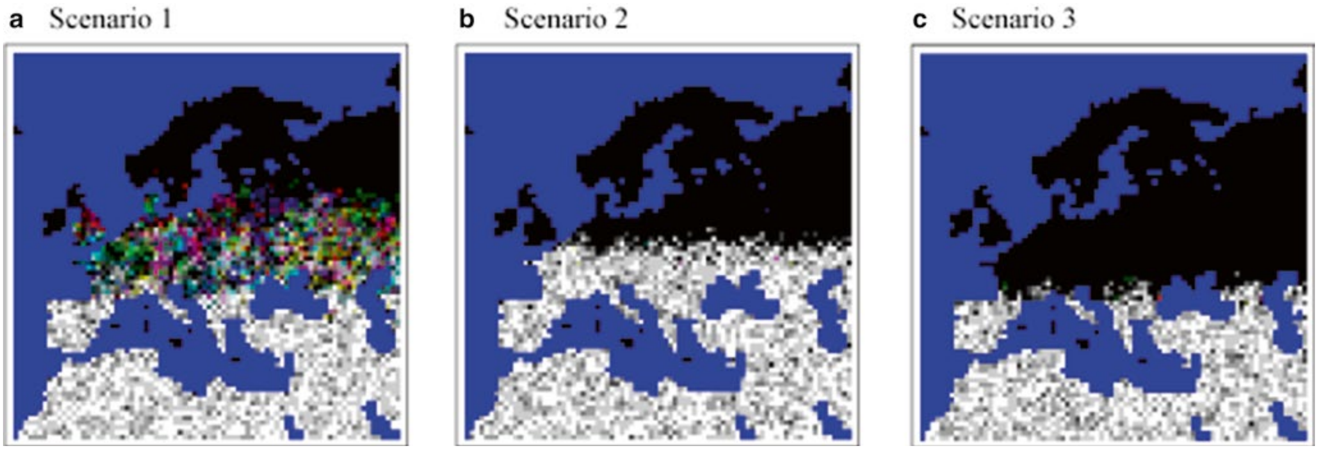


Fig. 15.4 Cultural diversity after modern humans spread into plains in scenario 1 (**a**), scenario 2 (**b**) and scenario 3 (**c**). Parameter values are the same as in Fig. 15.3. The densities of three forest-adapted techniques were displayed by *red*, *green*, and *blue*. Mixture of multiple techniques is represented by means of mixture of corresponding colors. As a result, cells where all the three techniques are equally dense look *white*. Plain-adapted techniques are not shown

It must be noted that in scenario 1 of the present model the difference in death rate between the two species plays a crucial role in the first and third phases of the replacement process. That is, in warm forests modern humans have a slightly lower death rate and therefore gradually replace Neanderthals under the current setup. Importantly, the major cause of the replacement is not necessarily the difference in death rate to obtain the pattern observed in scenario 1. I did some additional simulations, in which, instead of the death rate, the birth rate, dispersal rate, or the maximum number of techniques differed between the two species (results not shown). In all the cases, I found the same qualitative pattern as in the original model. Obviously, in all the cases other than the last (the maximum number of techniques), some advantage of modern humans other than learning is required, while in the last learning still plays a central role. Importantly, given that all the cases yield the same pattern, there is no a priori reason to assume that the last one was the truth. Thus, the present model can tell us little about the major cause of the replacement but can merely show the role of learning in shaping the pattern of the replacement. While some unknown advantage of modern humans causes the replacement in the first and third phases, innovation is crucial in the second phase. Parameters important in this phase are innovation and forgetting rates. If forgetting is too fast compared to innovation, modern humans can never be viable in the mid-latitude areas where vegetation is rapidly varying; as a result, the replacement can be stopped at this stage, so that Neanderthals do not go extinct. The required balance between innovation and forgetting depends in a non-trivial way on the maximum number of techniques, and further simulations are required to investigate this dependence.

In summary, the simulations predict that climate change and also the shape of the European continent play very important roles in determining the way the replacement of Neanderthals by modern humans occurs. In particular, the simulations explain (1) why Neanderthals survived exceptionally long in the Iberian Peninsula, (2) why it took some time for modern humans to start spreading into Europe, and (3) why cultural diversity of modern humans flourished particularly in the era of the replacement. Further the simulations predict that modern humans in Europe may have experienced a rather strong genetic bottleneck during their spreading into plains. It would be interesting to combine the current simulation model with population-genetic modeling to predict the genetic structure of the present European population in relation to nearby populations. The predicted genetic structure can be tested using most recent population-genetic data. However, before proceeding, we need to improve the model with respect to some unrealistic aspects or artificialities. For example, the current model ignores ice sheets, and therefore modern humans can even spread over the northland at the same rate as in lower-latitude areas. Although ice sheets would not affect the above qualitative conclusions, they may affect the prediction of genetic structure. We also need to take deserts into account to make the model more realistic. More important, in the current model the cultural diversity flourishes only in regions where vegetation is variable (Fig. 15.4a). In reality, however, modern humans' culture became diverse also in other regions. I do not yet have a good explanation for this discrepancy. The model also does not take into account the spread of culture by social learning between bands, which should in reality be possible.

Acknowledgments I sincerely thank the members of the RNMH project (especially B01, B02, and A01) for valuable comments. The world map used in this study was downloaded from "Share the Global Map" project (http://www.globalmap.org/english/index.html). This study was supported by Monbukagakusho grant 22101004.

References

Aoki K, Nakahashi W (2008) Evolution of learning in subdivided populations that occupy environmentally heterogeneous sites. Theor Popul Biol 74:356–368

Banks WE, d'Errico F, Peterson AT, Kageyama M, Sima A, Sanchez-Goni MF (2008) Neanderthal extinction by competitive exclusion. PLoS One 3(12):e3972. doi:10.1371/journal.pone.0003972

Finlayson C (2004) Neanderthals and modern humans: an ecological and evolutionary perspective. Cambridge University Press, Cambridge

Finlayson C, Carrion JS (2007) Rapid ecological turnover and its impact on Neanderthal and other human populations. Trends Ecol Evol 22:213–222

Hortola P, Martinez-Navarro B (2013) The Quaternary megafaunal extinction and the fate of Neanderthals: An integrative working hypothesis. Quat Int 295:69–72

Klein R (1999) The human career: human biological and cultural origins. University of Chicago Press, Chicago

Kobayashi Y, Aoki K (2012) Innovativeness, population size and cumulative cultural evolution. Theor Popul Biol 82:38–47

Shea JJ (2003) Neanderthals, competition, and the origin of modern human behavior in the Levant. Evol Anthropol 12: 173–187

Willis KJ (1996) Where did the flowers go? The fate of temperate European flora during glacial periods. Endeavour 20:110–114

Zilhao J (2000) The Ebro frontier: a model for the late extinction of Iberian Neanderthals. In: Stringer C, Barton RNE, Finlayson C (eds) Neanderthals on the edge: 150th anniversary conference of the Forbes' Quarry discovery, Gibraltar. Oxbow Books, Oxford, pp 111–121

Zilhao J, Davis SJM, Duare C, Soares AMM, Steier P et al (2010) Pego do Diabo (Loures, Portugal): dating the emergence of anatomically modernity in Westernmost Eurasia. PLoS One 5(1):e8880. doi:10.1371/journal.pone.0008880

Cultural Evolution and Learning Strategies in Hominids

16

Wataru Nakahashi

Abstract

The most significant difference between Neanderthals and modern humans can be observed in their culture. Compared with Neanderthals and other extinct hominids, modern human cultures have undergone cumulative improvement, which may have caused the great success of our species. I investigate the conditions for humans to improve many cultural traits to achieve a high level culture. I show that the increase of improvement ability brings about frequent improvements and high level culture, but it does not demand a larger brain provided brain size reflects the total number of cultural traits learned by each individual. On the other hand, the increase of individual and social learning abilities does not make culture attain a high level but demands a larger brain. Based on the model results, I present an evolutionary scenario of hominid learning abilities.

Keywords

Brain expansion • Cumulative culture • Hominid evolution

16.1 Introduction

What are humans? In order to answer this question, we need to know how humans evolved from apes (common ancestor) to our state today (note that Miocene hominoids are often described as "apes" in paleoanthropology, although their features were somewhat different from extant apes). Anthropological studies have shown that the history of hominid evolution consists of three important stages. The first stage is characterized by the separation of human lineage from the chimpanzee lineage, which occurred five to seven million years ago, and the subsequent evolution of bipedalism in hominids. The human lineage thereafter started to evolve to humans while the chimpanzee lineage has remained in the realm of apes today. The second stage is characterized by the emergence of the genus *Homo* and the beginning of brain expansion, which occurred two to three million years ago. Around this time, hominids started to use stone tools, which allowed them to enhance adaptation and broaden the distribution to outside Africa. The third stage is characterized by the emergence of *Homo sapiens* (modern humans) around 200,000 years ago, which marked also the emergence of diverse and complicated culture and behavior. Finally, the distribution of humans expanded to the whole world, achieving an explosive increase in population.

Investigation of the replacement of Neanderthals by modern humans focuses on the third stage. If we know the differences between Neanderthals and modern humans, we can acquire a hint to solve the mystery of human prosperity. Since the emergence of *Homo sapiens* occurred in the evolutionary history of hominids, let us explore the common and different characteristics of the two species from the perspective of hominid evolution.

Although it was once believed that Neanderthal ability for bipedalism was lower than modern humans (Boule 1923), it is now believed that there was no significant difference in

W. Nakahashi (✉)
Department of Human Biology and Anatomy, Graduate School of Medicine, University of the Ryukyus, Uehara 207, Nishihara-cho, Nakagami, Okinawa 903-0215, Japan
e-mail: w.nakahashi@gmail.com

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_16,

bipedalism between the two species (Straus and Cave 1957). Moreover, Neanderthals had almost the same (or slightly large) brain size as modern humans (Robson and Wood 2008). Arguably, the most significant difference can be observed in their culture. The Mousterian tradition of Neanderthals was almost static for hundreds of thousands of years (Akazawa et al. 1998), whereas modern human culture changed frequently during and after the Upper Paleolithic in Europe (Bar-Yosef 2002) and the Middle Stone Age in Africa (McBrearty and Brooks 2000). It is often said that human culture is cumulative, that is, human culture evolves over time through iterative improvements in technology and reaches a high level that cannot be invented by a single individual (Boyd and Richerson 1985; Tomasello 1999). We can consider that the accumulation speed of culture was far slower in Neanderthals than in modern humans.

What makes human culture? Since cultural traits are transmitted among nonrelatives by social learning, large group size and high social learning ability are obviously necessary conditions. The evolution of group structure in hominids is one of the key topics in anthropology (Nakahashi and Horiuchi 2012). Fossil evidence shows that A.L.333, an *Australopithecus afarensis* group known as the "First Family," may have included at least 17 hominids: nine adults, three adolescents, and five juveniles (Johanson 2004), which is similar to the size and composition of a band in current hunter-gatherers societies that have a total of 25 individuals (Terashima 1985). Although archaeological evidence suggests that Neanderthal social units had, on average, a total of 8–10 individuals (Vallverdú et al. 2010), we can consider that before the split of Neanderthals and modern humans, group size evolved to be sufficiently large for cultural traits to be transmitted among nonrelatives.

The evolution of social learning ability has been discussed for a long time, where many physical anthropologists have focused on the mechanical capacity of spoken language (verbal communication). Lieberman and Crelin (1971) investigated skeletal structure and supralaryngeal vocal tract of Neanderthals and argued that Neanderthals did not have the anatomical prerequisites for producing the full range of modern human speech. However many researchers have criticized their reconstruction of Neanderthal fossil as being inaccurate (reviewed in Albanese 1994). Arensburg et al. (1989) argued that a Neanderthal hyoid from Kebara is almost identical in size and shape to the hyoid of modern humans so that the morphological basis for human speech capability was fully developed in Neanderthals. However, this view has not been well accepted because we lack information on the hyoids of other fossil hominids (Laitman et al. 1990). Kay et al. (1998) investigated the hypoglossal canal size in fossil hominids and argued that although the vocal abilities of *Australopithecus* were not advanced significantly over those of chimpanzees, those of *Homo* may have been essentially modern by at least 400,000 years ago: that is, the vocal abilities of Neanderthals were the same as those of modern humans. MacLarnon and Hewitt (1999) showed that modern humans and Neanderthals have an expanded thoracic vertebral canal compared with australopithecines and *Homo ergaster*, who had canals of the same relative size as extant nonhuman primates, suggesting that Neanderthals had the same vocal abilities as modern humans. Aside from physical anthropology, Neanderthal ability for communication has been studied. In experimental archaeology, Ohnuma et al. (1997) showed that spoken language is unnecessary in learning how to make Levallois flakes, typical stone tools of Neanderthals. In genetics, Krause et al. (2007) showed that Neanderthal *FOXP2*, a gene that may be involved in the development of speech and language, was identical to that of modern humans. In short, although the capacity for language in Neanderthals is not perfectly supported, there is no critical evidence that rejects it.

If Neanderthals had the same ability for social learning (language), how can we explain the difference between their and our cultures? As explained above, Neanderthal culture was static, which may have been supported by their accurate social learning. On the other hand, modern human culture changed frequently. It may be unrealistic to consider that modern human social learning is less accurate than Neanderthals, so we should assume that modern humans have an additional learning ability, which drives cultural change.

One of the critical problems for the assumption of an additional learning ability in modern humans is the fact that Neanderthals had almost the same brain size as modern humans. More complex technologies (e.g., stone tools, bone tools, fire), which may have demanded higher learning abilities for their acquisition, emerged as the brain of *Homo* evolved to be larger (reviewed in Klein 1999), suggesting that hominid brain size reflects learning abilities. Researches on the variation of animal brain size have also suggested that brain size reflects ability for sociality (Dunbar 1998) or cultural intelligence (van Schaik and Burkart 2011; van Schaik et al. 2012), which may affect (or be affected by) learning abilities. If Neanderthals had a smaller brain than modern humans, many researchers might argue that Neanderthals went extinct because they had lower learning ability or lacked some abilities. Although some researchers consider that some learning abilities of Neanderthals were lower (Mithen 1996, 2005; Klein and Edgar 2002), no one has theoretically explained why Neanderthals needed the same brain size.

I assume that this additional ability is "improvement ability," the ability for improving socially learned cultural traits. It is obvious that cumulative culture is never brought about by individual learning (acquiring cultural traits independently of others' traits) or by simple social learning (copying others' cultural traits without modification). Only when humans learn cultural traits from others and improve on (modify) them can culture evolve to a high level such as no single individual can invent independently. In this paper, I consider three ways of learning, individual learning (IL), simple social learning (SL) and social improvement (SI), and discuss under what conditions the human ability to improve many cultural traits to create high level culture evolved ("cultural level" is defined as average utility of beneficial cultural traits). Based on the model results, I discuss how the abilities for these ways of learning evolved in hominids and how we can explain the same brain size problem.

16.2 Model

Figure 16.1 describes the model. In the following, I explain the model by referring to this figure. The aim of this model is to investigate under what conditions improvement ability will evolve, thus permitting organisms to improve many cultural traits to achieve high level culture.

Consider an infinite population with infinitely many kinds of cultural traits (know-how, information, technology, etc.) generated by individual learning, the mistakes of social learning, and improvement (modification) of socially learned cultural traits. Cultural traits can be classified into two categories, beneficial and useless, and each beneficial cultural trait has different utility. In Fig. 16.1, beneficial cultural traits are represented by white circles and useless ones by black circles. The size of a white circle indicates the utility of the beneficial cultural trait. In this paper, the term "utility" means the efficiency of performance of a cultural trait in promoting the acquisition of energy/resources that affect the fitness (fertility) of organisms, and does not mean a subjective measure of satisfaction. Useless cultural traits have no utility and therefore do not affect the fitness of organisms. Organisms cannot distinguish between beneficial and useless cultural traits, and acquire them by individual learning, simple social learning, and social improvement (acquiring a cultural trait by simple social learning and modifying it). The number of cultural traits they learn ("learning capacity") is determined by their strategy gene, i.e., an organism with strategy (n,m,l) acquires n cultural traits by individual learning, m by simple social learning, and l by social improvement. That is, individual learning capacity is n, simple social learning capacity is m, and social improvement capacity is l. In Fig. 16.1, the focal organism in the center of the figure has the learning strategy (4,3,3), so that it acquires four cultural traits by individual learning (shaded arrows), three by simple social learning (white arrows), and three by social improvement (gray arrows). Although many organisms may share the same cultural traits, the possibility that an organism learns the same cultural trait more than once can be disregarded because, by assumption, there are infinitely many kinds of cultural traits and organisms acquire a finite number of cultural traits.

In the individual learning process, organisms acquire a new cultural trait by themselves, for example, by trial-and-error or insight. Let the probability of acquiring a beneficial

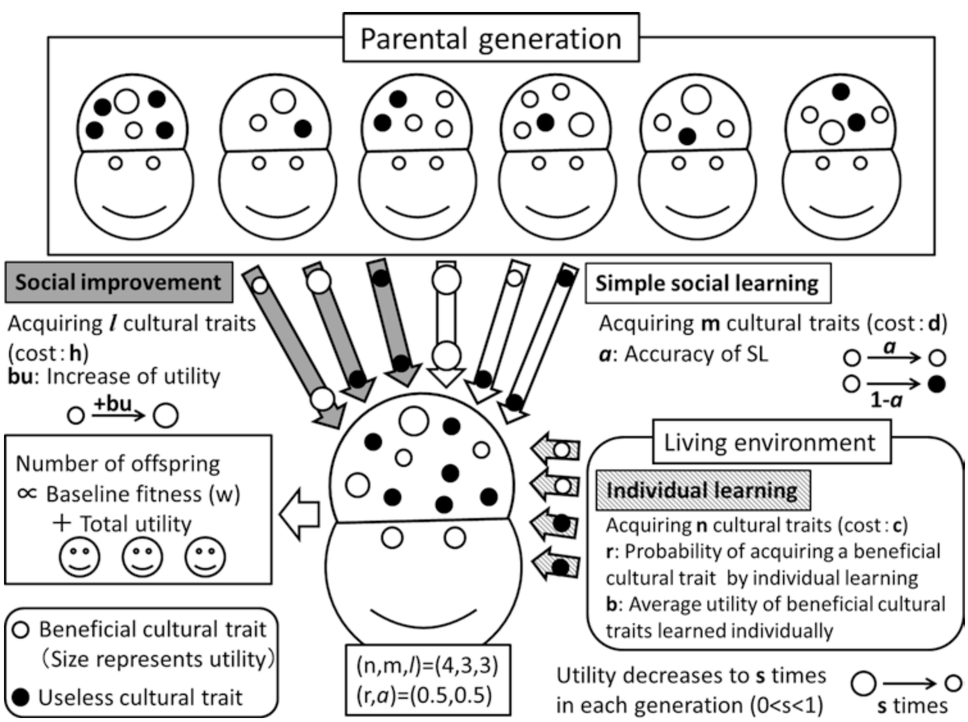


Fig. 16.1 The graphical explanation of the model

cultural trait (success rate of individual learning) be r ($0<r<1$) and the average utility of the beneficial cultural trait (individual "learning level") be b. In Fig. 16.1, we assume the organism in the center has success rate of individual learning $r=0.5$, so that when it acquires four cultural traits by individual learning, on average, it acquires two beneficial cultural traits (two white circles) with average utility b and two useless cultural traits. The size of white circles in the shaded arrows describes individual learning level.

In the simple social learning process, organisms copy a cultural trait from a random member of their parental generation (oblique transmission) and the cultural trait is randomly picked from the repertory of the target's cultural traits pool. In Fig. 16.1, organisms in upper square belong to the parental generation, and they have various kinds of cultural traits (white and black circles), from which the focal organism in the center learns socially. Let the probability of copying another's cultural trait accurately (accuracy of social learning) be a ($0<a<1$). In Fig. 16.1, we assume the organism in the center has accuracy of social learning $a=0.5$, so that when it observes two beneficial cultural traits (in white arrows, there initially exist two white circles), on average, it successfully acquires one beneficial cultural trait (in the left white arrow, a white circle remains white and its size holds), while the other beneficial trait is inaccurately copied and becomes one useless cultural trait (in the center white arrow, a white circle changes to be black during the simple social learning process). We reject the possibility that a useless cultural trait becomes beneficial by mistakes of social learning, so in the right white arrow, a black circle remains black.

In the social improvement process, organisms initially acquire a cultural trait by oblique transmission as in simple social learning and then modify it. If they learn a beneficial cultural trait accurately, they increase its utility. Let the average increase of utility be bu ($u>0$). That is, we assume that the increase of utility by social improvement is proportional to individual learning level, and the ratio is u (improvement level). In Fig. 16.1, we assume the organism in the center has $a=0.5$, so that when it observes two beneficial cultural traits (in gray arrows, there initially exist two white circles), on average, it acquires one beneficial cultural trait and increases its utility (in the left gray arrow, a white circle remains white and its size increases) and one useless cultural trait (in the center gray arrow, a white circle changes to be black during the social improvement process). We reject the possibility that a useless cultural trait becomes beneficial by social improvement, so in the right gray arrow, a black circle remains black.

The life cycle of organisms consists of two stages: learning/viability selection stage and fertility selection stage. In the learning/viability selection stage, each organism learns cultural traits piece by piece and pays a small viability cost for each learning activity. It costs $1-e^{-c}$ to acquire a cultural trait by individual learning, $1-e^{-d}$ by simple social learning, and $1-e^{-h}$ by social improvement. Therefore, the probability that an organism with strategy (n,m,l) can survive and go to the next stage is $[1-(1-e^{-c})]^n[1-(1-e^{-d})]^m[1-(1-e^{-h})]^l = e^{-cn-dm-hl}$. Since social improvement requires an additional effort compared with simple social learning, we may assume $d<h$ in the following analysis.

In the fertility selection stage, the fitness of an organism is determined by the total utility of beneficial cultural traits acquired during the learning/viability selection stage. The fitness of an organism which has k beneficial cultural traits with average utility f is expressed as $w+kf$, where w is the baseline fitness of organisms. We assume fertility selection: the number of their offspring is proportional to $w+kf$. In Fig. 16.1, this stage is described in the left square. All organisms die soon after their cultural traits are passed on to the next generation.

In each generation before the learning/viability selection stage, the environment changes, and the utility of beneficial cultural traits decreases to s times ($0<s<1$) its previous value. That is, parameter s represents the stability of the environment. Note that this environmental change does not make a beneficial cultural trait (completely) useless. For example, $s=0.8$ implies that organisms can get eight head of game by a hunting method that previously yielded ten head of game in the parental generation. Alternatively, we could consider a different type of environmental change, one that renders a beneficial cultural trait useless. However, since the accuracy of social learning, a, in this model represents the probability that a beneficial cultural trait remains beneficial in the next generation, this latter type of environmental change can be included in parameter a (see Nakahashi 2010). In other words, parameter a can be regarded as the product of the probability of copying others' cultural trait accurately, and the probability of a beneficial cultural trait not becoming useless by environmental change in the next generation.

Baseline fitness, w, is the contribution of genetic (innate) traits and corresponds to the fitness of organisms with no learned cultural traits. The baseline fitness may be greater when genetic traits are sufficiently adaptive in a particular environment. Such an environment can be considered to be mild for organisms, so baseline fitness w reflects the mildness of the environment.

16.3 Analysis and Result

I obtain the evolutionarily stable learning strategy $\left(\hat{n},\hat{m},\hat{l}\right)$. Here, $\hat{n}$, $\hat{m}$, and $\hat{l}$ are the cultural capacities, i.e. the numbers of cultural traits acquired by the three ways of learning. An evolutionarily stable strategy (ESS) is a strategy that is stable to the invasion of rare mutants of small effect (mutants cannot increase their frequency), provided once the population is fixed for the strategy (Maynard Smith 1982).

I also confirmed that the ESS is favored by natural selection in this model by a numerical simulation (shown in Nakahashi 2013). Therefore, the ESS can be considered to be the evolutionary outcome of competition among learning strategies under each condition.

Assume that a mutant strategy (n,m,l) (strategy B) is introduced at low frequency into an equilibrium population whose members all use the strategy (n^*,m^*,l^*) (strategy A). Then, the fitness of the mutant is

$$W(B,A) = \left[w + rbn + a\hat{x}\hat{g}m + a\hat{x}\left(\hat{g} + bu\right)l\right] e^{-cn-dm-hl} \quad (16.1)$$

where $\hat{x}$ is the probability that an organism at this equilibrium acquires a beneficial cultural trait by social learning, and $\hat{g}$ is the average utility of the beneficial cultural trait acquired by simple social learning. This equation implies that the survivability of a mutant over the learning/viability selection stage is $e^{-cn-dm-hl}$, during which it acquires rn beneficial cultural traits with an average utility b by individual learning, $a\hat{x}m$ beneficial traits with average utility $\hat{g}$ by simple social learning, and $a\hat{x}l$ beneficial traits with average utility $\hat{g}+bu$ by social improvement, so that its number of offspring in the fertility selection stage is proportional to $w + rbn + a\hat{x}\hat{g}m + a\hat{x}\left(\hat{g}+bu\right)l$. If $W(B,A) < W(A,A)$ is satisfied for all B $(B \neq A)$, strategy A is the ESS.

Although the ESS can be obtained analytically, the derivation (shown in Nakahashi 2013) is long, so I only present the results graphically in this paper. Figure 16.2 shows the effects of the parameters on the ESS $\left(\hat{n},\hat{m},\hat{l}\right)$ and cultural level (average utility of beneficial cultural traits) in the ESS population. In these figures, one parameter is varied while the other parameters are held constant. Although I assume $c>h>d$ in these figures, general tendency of the results does not change when $h>c>d$. What we want to know is the condition for social improvement capacity, $\hat{l}$, to be large (many cultural traits to be improved) and cultural level to be high.

As shown in Fig. 16.2a, the ESS social improvement capacity is maximized when environmental stability, s, is intermediate. This can be explained as follows. When environmental stability is high, socially learned beneficial cultural traits are highly effective without modification; it is better for organisms to invest more effort in simple social learning than in social improvement. When environmental stability is low, socially learned beneficial cultural traits are essentially ineffective even if they are modified, so individual learning becomes more adaptive. When environmental stability is intermediate, socially learned beneficial cultural traits are relatively ineffective if unmodified but highly effective if modified, so that social improvement is adaptive. Moreover, cultural level increases when environmental stability, s, is intermediate. This is because, when environmental stability is intermediate, the proportion of social improvement capacity among total learning capacity increases so that beneficial cultural traits are often improved to the point of high utility.

As shown in Fig. 16.2b, each learning capacity increases as baseline fitness, w, decreases. This is because when the effect of genetic traits decreases, the relative importance of cultural traits increases. In other words, when the environment is sufficiently mild for organisms to survive, learning is meaningless (unnecessary) and, thus, never evolves. On the other hand, cultural level is independent of baseline fitness, w. This is because the evolutionarily stable proportions of each learning capacity, as opposed to their absolute values, are independent of baseline fitness.

As shown in Fig. 16.2c, each learning capacity increases as the success rate of individual learning, r, increases. This is because individual learning is naturally adaptive when success rate of individual learning is high and, since the proportion of beneficial cultural traits increases as the success rate of individual learning increases, social learning also becomes adaptive. On the other hand, cultural level is independent of the success rate of individual learning, r. This is because every way of learning receives the same advantage from high success rate of individual learning so that the proportions of each learning capacity are independent of the success rate of individual learning.

As shown in Fig. 16.2d, social improvement capacity increases as individual learning level, b, increases. This is because every way of learning becomes adaptive when cultural traits have higher utility. Moreover, cultural level increases when individual learning level, b, is high. This is because cultural traits with higher utility are innovated when individual learning level is high.

As shown in Fig. 16.2e, social improvement capacity increases as the accuracy of social learning, a, increases. This is reasonable because social improvement is effective only when organisms accurately learn cultural traits socially. On the other hand, cultural level decreases as the accuracy of social learning, a, increases, provided social improvement capacity does not exist at the ESS (i.e. $\hat{l}=0$). This can be explained as follows. As the proportion of simple social learning capacity among total learning capacity increases, a large fraction of beneficial cultural traits are transmitted between generations without improvement and their utility decreases during transmission process by environmental change, so that cultural level decreases. As the proportion of social improvement capacity among total learning capacity increases, a large fraction of beneficial cultural traits are improved, so that cultural level increases. Since both simple social learning capacity and social improvement capacity increase proportionally as the accuracy of social learning increases, cultural level is decreased by simple social learning and increased by social improvement. These two effects cancel and cultural level is constant in a provided social improvement exists, whereas cultural level decreases in a

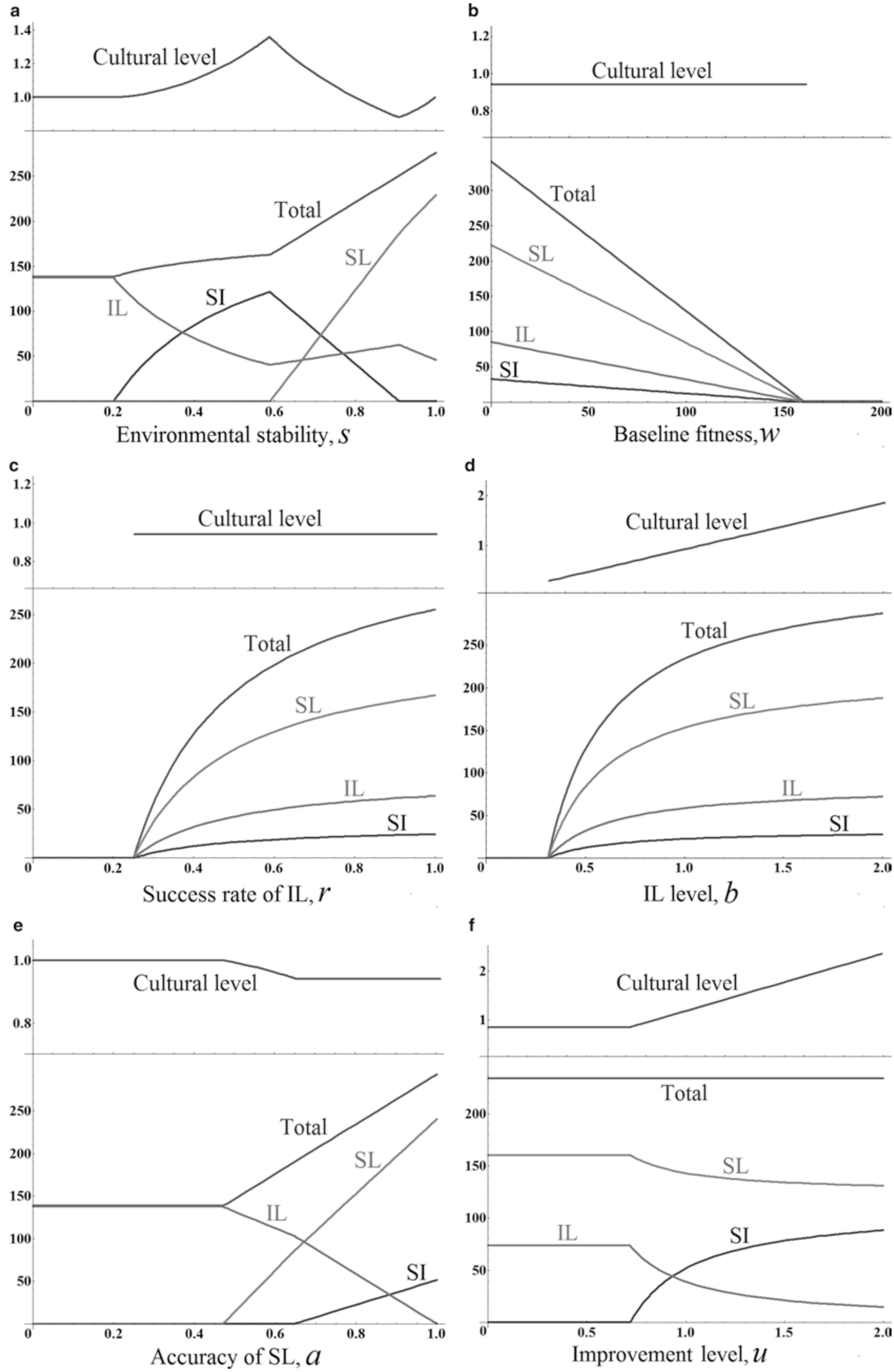


Fig. 16.2 The effects of parameters on the ESS $(IL_*, SL_*, SI) = (\hat{n}_*, \hat{m}_*, \hat{l})$ (*bottom*) and cultural level, $\hat{g}/s$, in the ESS population (*top*). Each figure shows the effect of (**a**) environmental stability, *s*, (**b**) baseline fitness, *w*, (**c**) success rate of individual learning, *r*, (**d**) individual learning level, *b*, (**e**) accuracy of social learning, *a*, and (**f**) improvement level, *u*. Parameters are $c=0.005, d=0.002, h=0.004$, and $s=0.85, w=50, r=0.8, b=1, a=0.8, u=0.8$ when each parameter is not a variable

because of the effect of simple social learning when social improvement does not exist. Moreover, since parameter *a* can be correlated with the probability that beneficial cultural traits will not become useless by environmental change in the next generation, we may consider that social improvement capacity increases and cultural level decreases (or remains constant) when the probability that beneficial cultural traits become useless by environmental change is small.

As shown in Fig. 16.2f, social improvement capacity increases, as expected, when improvement level, *u*, is high. Moreover, cultural level increases as improvement level, *u*, increases. This is because the proportion of social improvement capacity among total learning capacity increases with *u*. In other words, when improvement level is high, iterative improvements of cultural traits occur, and cultural traits reach a level that cannot be invented by a single individual, i.e., the increase in the level of improvement results in cumulative culture. Interestingly, total learning capacity ($\hat{n}+\hat{m}+\hat{l}$) is constant provided simple social leaning capacity is positive ($\hat{m}>0$). This is because social improvement has properties of both individual learning (innovating) and simple social learning (imitating), so that organisms can use social improvement instead of individual and simple social learning. Therefore, when improvement level increases, the merit of social improvement increases and relative merit of individual and simple social learning decreases so that organisms increase the capacity of social improvement and decrease those of individual and simple social learning.

In conclusion, social improvement capacity evolves and organisms improve many cultural traits when environmental stability is intermediate; baseline fitness is small; and the success rate of individual learning, individual learning level, accuracy of social learning, and improvement level are all high. Cultural level increases when environmental stability is intermediate; and the individual learning level and improvement level are both high.

16.4 Discussion

In this paper, I have studied the conditions that favor the evolution of organisms that improve many cultural traits to achieve high level culture. I have analyzed the effect of environmental factors and learning abilities. Hereafter I use the term "learning ability" for parameters *r*, *b*, *a*, and *u*. Although parameters *n*, *m*, and *l* may also be considered as learning abilities, I use the term "learning capacity" for them. I have shown that when organisms have higher improvement ability (ability for improving the utility of socially learned cultural traits), many cultural traits are improved and the average utility of beneficial cultural traits (cultural level) increases. This result is quite reasonable, because biological organisms may evolve to increase the dependence on their specialty. If improvement ability was different between Neanderthals and modern humans, the cultural differences between the two species can be explained.

This hypothesis is somewhat similar to that proposed by Mithen (1996) who argued that cognitive fluidity, by which modern humans can combine different ways of processing knowledge, enables the construction of complex artifacts, and which may have been lacking in Neanderthals. That is, in order to improve the utility of socially learned cultural traits, cognitive fluidity between individual and social learning may be necessary. Note that we cannot include detailed cognitive mechanisms in mathematical models, so that learning strategies (abilities) are defined as their outputs (results). The mechanisms that underlie the outputs are in the black box in mathematical models.

If improvement ability was different between Neanderthals and modern humans, a remaining problem is why both species had almost the same brain size while one had higher ability than the other. I propose that if the brain size is strongly affected by total learning capacity (number of cultural traits learned by each individual), which may correspond to the amount of knowledge or the memory capacity, this problem is clearly solved. From the evidence of brain science, acquisition of knowledge causes the enlargement of the relevant brain region. For example, taxi drivers have larger posterior hippocampi (Maguire et al. 2000; Woollett and Maguire 2011). Gray matter is partially used for the storage of knowledge. If total learning capacity is large, individuals have to store more knowledge in their brains, so a large brain is necessary. Therefore, it is reasonable to consider that brain size correlates with total learning capacity. This hypothesis does not contradict other hypotheses of the evolution of animal brain size, such as the social brain hypothesis (Dunbar 1998) or the cultural intelligence hypothesis (van Schaik and Burkart 2011; van Schaik et al. 2012), because individuals may need to store much knowledge to keep high ability for sociality or cultural intelligence.

By assuming that brain size reflects total learning capacity, how can we explain hominid evolutionary history from model results? It is common knowledge that the brain started to evolve into a larger organ when the genus *Homo* emerged, but the increase in brain size stopped at the evolutionary stages of Neanderthals and early *Homo sapiens*. If individual and (simple) social learning abilities had increased in the genus *Homo*, this may have caused the increase in the brain size because total learning capacity increases as these abilities increase (see Fig. 16.2c–e). At the evolutionary stages of Neanderthals and early *Homo sapiens*, individual and social learning abilities stopped increasing, but improvement ability evolved to a high level only in *Homo sapiens*, which caused our highly cumulative culture, but did not entail the increase of brain size because total learning capacity is independent of improvement ability (see Fig. 16.2f). Figure 16.3 describes this evolutionary scenario of hominid learning abilities and brain size.

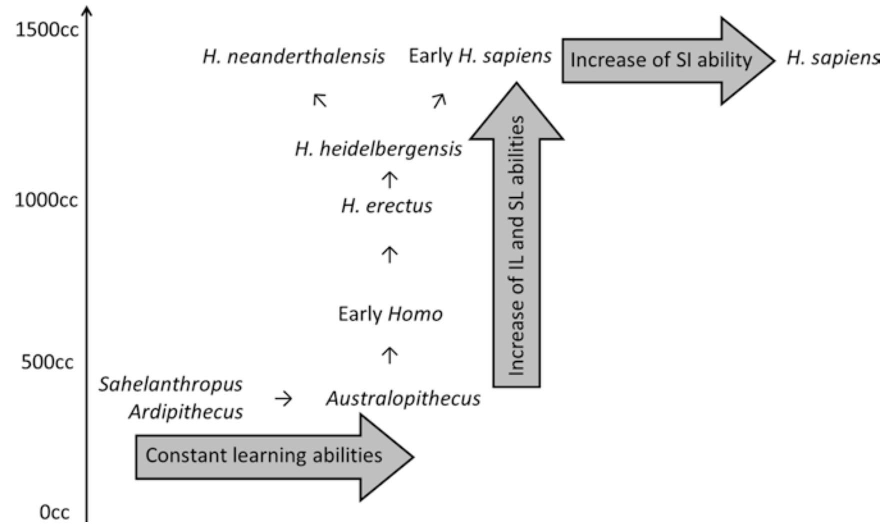


Fig. 16.3 The evolutionary scenario of hominid learning abilities and brain size suggested by the model

Although this model can show the conditions for each learning capacity to increase, it does not explain why high learning abilities evolved in the genus *Homo*. However, we can consider that an increase in the dependence on a way of learning (learning capacity) may trigger an increase of the ability for the way of learning (Nakahashi 2010). For example, individual learning ability starts to increase when the dependence on individual learning exceeds a threshold value. As shown in Fig. 16.2b, when the environment deteriorates drastically, the dependence on learning increases. Therefore, if the ancestor of the genus *Homo* experienced drastic environmental change, the enlargement of brain size in the genus *Homo* can be explained. From paleoclimatic evidence, African climate became drier about 2–3 million years ago (deMenocal 2004, 2011; Behrensmeyer 2006; Elton 2008), and then (at least) two new hominid lineages, "robust" australopithecine and the genus *Homo*, emerged from the ancestral lineage of "gracile" australopithecine. Robust australopithecine, which had uniquely large cheek teeth and strong jaw musculature, was adapted to processing coarse vegetable matter, which was the most suitable food in the drier environment, although their diets may have been various in each species (Ungar and Sponheimer 2011). Early *Homo* had relatively gracile teeth and mandible (Suwa et al. 1996), so that they might not have been well adapted to the food in the drier environment. Therefore, the baseline fitness of early *Homo* might have been smaller than that of robust australopithecine, which caused the enlargement of their brain. In other words, the African climate change some 2–3 million years ago might have caused the emergence of robust australopithecine and the genus *Homo*; robust australopithecine adapted to the drier environment by developing stronger teeth and mandible, and the genus *Homo*, by improving their learning abilities, which caused the increase of their learning capacities and brain size.

As shown in Fig. 16.2c, d, (simple) social learning capacity increases with individual learning ability (success rate of individual learning and the utility of cultural trait learned individually), so the evolution of high social learning ability may be triggered by high individual learning ability. Similarly, as shown in Fig. 16.2e, social improvement capacity increases with simple social learning ability (accuracy of social learning), so the evolution of high improvement ability may be triggered by high social learning ability. In other words, we can consider that the evolution of high individual learning ability may precede that of high simple social learning ability, which may precede that of high improvement ability.

Once learning ability started to increase, this entails the increase of learning capacity so that a positive feedback occurs and learning ability and capacity keep increasing until the cost for developing high learning ability and capacity becomes too large. Human females suffer large cost for delivering large brain babies (Tague and Lovejoy 1986), although we are born premature compared with other primates. That is, at the evolutionary stages of Neanderthals and early *Homo sapiens*, the cost for large brain may have become so large (Ponce de Leon et al. 2008) that brain size stopped increasing. Therefore, individual learning ability and simple social learning ability may also have stopped increasing.

The key problem is why Neanderthals did not increase improvement ability if social learning ability was the same as modern humans. As shown in Fig. 16.2a, social improvement capacity increases when environmental stability is intermediate. Therefore, if early *Homo sapiens* in Africa experienced an environment of intermediate stability and Neanderthals in Europe experienced different environmental stability, the different evolutionary outcome of both species can be explained. Neanderthals moved south when climate changed to be cold, which may have reduced the impact of environmental change and the importance of improvement. Isotopic evidence indicates that European Neanderthals had a similar diet (large herbivores) through time and in different regions (Richards and Trinkaus 2009). The cost for moving to similar environments as they previously lived may have been smaller than that for challenging different environments. This may possibly be the reason why Neanderthals had not increased improvement ability. On the other hand, if population density of Africa had been higher than that of Eurasia, it may have been difficult for African people to move to reduce the impact of environmental change because most habitats are preoccupied. Genetic evidence suggests smaller (effective) population size in Neanderthals (Briggs et al. 2009) and in Denisovans (Meyer et al. 2012) than in modern humans, and population density of hominids tends to be low in high latitude (Grove et al. 2012). Although it is uncertain where first *Homo sapiens* appeared, at least some hominid groups in Africa may have experienced relatively strong impact of environmental change, which may have caused the evolution of high improvement ability.

In conclusion, the cultural differences of Neanderthals and modern humans can be explained by their different ability for improving socially learned cultural traits. The same size brain of both species can also be explained if we assume brain size reflects total number of cultural traits learned by each individual. The difference of environmental stability both species experienced may have caused the evolution of their different learning ability.

References

Akazawa T, Aoki K, Bar-Yosef O (1998) Neandertals and modern humans in western Asia. Plenum, New York

Albanese J (1994) Neanderthal speech. Totem Univ West Ontario. J Anthropol 1:99–105

Arensburg B, Tillier AM, Vandermeerschet B et al (1989) A Middle Paleolithic human hyoid bone. Nature 338:758–760

Bar-Yosef O (2002) The Upper Paleolithic revolution. Annu Rev Anthropol 31:363–393

Behrensmeyer AK (2006) Climate change and human evolution. Science 311:476–478

Boule M (1923) Fossil men. Oliver and Boyd, Edinburgh

Boyd R, Richerson PJ (1985) Culture and the evolutionary process. University of Chicago Press, Chicago

Briggs AW, Good JM, Green RE et al (2009) Targeted retrieval and analysis of five Neandertal mtDNA genomes. Science 325: 318–321

deMenocal PB (2004) African climate change and faunal evolution during the Pliocene–Pleistocene. Earth Planet Sci Lett 220:3–24

deMenocal PB (2011) Climate and human evolution. Science 331: 540–542

Dunbar RIM (1998) The social brain hypothesis. Evol Anthropol 6: 178–190

Elton S (2008) The environmental context of human evolutionary history in Eurasia and Africa. J Anatomy 212:377–393

Grove M, Pearce E, Dunbar RIM (2012) Fission-fusion and the evolution of hominin social systems. J Hum Evol 62:191–200

Johanson DC (2004) Lucy, thirty years later: an expanded view of *Australopithecus afarensis*. J Anthropol Res 60:465–486

Kay RF, Cartmill M, Balow M (1998) The hypoglossal canal and the origin of human vocal behavior. Proc Natl Acad Sci U S A 95:5417–5419

Klein RG (1999) Human career, 2nd edn. University of Chicago Press, Chicago

Klein RG, Edgar B (2002) The dawn of human culture. Wiley, New York

Krause J, Lalueza-Fox C, Orlando L et al (2007) The derived FOXP2 variant of modern humans was shared with Neandertals. Curr Biol 17:1908–1912

Laitman JT, Reidenberg JS, Gannon PJ et al (1990) The kebara hyoid: what can it tell us about the evolution of the hominid vocal tract? Am J Phys Anthropol 81:254

Lieberman P, Crelin ES (1971) On the speech of Neanderthal man. Linguist Inq 2:203–222

MacLarnon AM, Hewitt GP (1999) The evolution of human speech: the role of enhanced breathing control. Am J Phys Anthropol 109:341–363

Maguire EA, Gadian DG, Johnsrude IS et al (2000) Navigation-related structural change in the hippocampi of taxi drivers. Proc Natl Acad Sci U S A 97:4398–4403

Maynard Smith J (1982) Evolution and the theory of games. Cambridge University Press, Cambridge

McBrearty S, Brooks A (2000) The revolution that wasn't: a new interpretation of the origin of modern human behavior. J Hum Evol 39:453–563

Meyer M, Kircher M, Gansauge MT et al (2012) A high-coverage genome sequence from an archaic denisovan individual. Science 338:222–226

Mithen SJ (1996) The prehistory of the mind: a search for the origins of art, religion, and science. Thames and Hudson, London

Mithen SJ (2005) The singing Neanderthals: the origins of music, language, mind and body. Harvard University Press, Cambridge

Nakahashi W (2010) Evolution of learning capacities and learning levels. Theor Popul Biol 78:211–224

Nakahashi W (2013) Evolution of improvement and cumulative culture. Theor Popul Biol 83:30–38

Nakahashi W, Horiuchi S (2012) Evolution of ape and human mating systems. J Theor Biol 296:56–64

Ohnuma K, Aoki K, Akazawa T (1997) Transmission of tool-making through verbal and non-verbal communication: preliminary experiments in Levallois flake production. Anthropol Sci 105:159–168

Ponce de Leon MSP, Golovanova L, Doronichev V et al (2008) Neanderthal brain size at birth provides insights into the evolution of human life history. Proc Natl Acad Sci U S A 105:13764–13768

Richards MP, Trinkaus E (2009) Isotopic evidence for the diets of European Neanderthals and early modern humans. Proc Natl Acad Sci U S A 106:16034–16039

Robson SL, Wood B (2008) Hominin life history: reconstruction and evolution. J Anatomy 212:394–425

Straus WR Jr, Cave AJE (1957) Pathology and the posture of Neanderthal man. Quart Rev Biol 32:348–363

Suwa G, White TD, Howell FC (1996) Mandibular postcanine dentition from the Shungura formation, Ethiopia: crown morphology, taxonomic allocations, and plio-pleistocene hominid evolution. Am J Phys Anthropol 101:247–282

Tague RG, Lovejoy CO (1986) The obstetric pelvis of A.L. 288–1 (Lucy). J Hum Evol 15:237–255

Terashima H (1985) Variation and composition principles of the residence group (band) of the Mbuti Pygmies-beyond a typical/atypical dichotomy. Afr Stud Monogr Suppl Issue 4:103–120

Tomasello M (1999) The cultural origins of human cognition. Harvard University Press, Harvard

Ungar PS, Sponheimer M (2011) The diets of early hominins. Science 334:190–193

Vallverdú J, Vaquero M, Cáceres I et al (2010) Sleeping activity area within the site structure of archaic human groups: evidence from Abric Romaní level N combustion activity areas. Curr Anthropol 51:137–145

van Schaik CP, Burkart JM (2011) Social learning and evolution: the cultural intelligence hypothesis. Philos Trans R Soc B 366:1008–1016

van Schaik CP, Isler K, Burkart JM (2012) Explaining brain size variation: from social to cultural brain. Trend Cognitive Sci 16:277–284

Woollett K, Maguire EA (2011) Acquiring "the knowledge" of London's layout drives structural brain changes. Curr Biol 21:2109–2114

A Mathematical Model of Cultural Interactions Between Modern and Archaic Humans

17

Wataru Nakahashi

Abstract

In order to understand the different patterns of cultural change in modern and archaic humans, I propose a new model of cultural evolution. I show that when we consider one isolated population, cultural evolutionary speed increases when individuals have higher creativity to explore cultural traits more widely, accurately judge the utility of cultural traits (strong direct bias), do not strongly rely on the population mean, increase the exploration range according to the variety of socially learned cultural traits (condition dependent exploration), and make smaller errors in social learning. The number of exemplars, population size, relatedness (similarity) of cultural traits in exemplars, and one-to-many (teacher) transmission have little effect on cultural evolutionary speed provided population size is large. Next, I study the effect of cultural interactions between modern and archaic humans. I show that the different patterns of cultural change in Africa, Europe, and Asia around 20,000–200,000 years ago can be explained by differences in dispersal processes of modern humans among the regions. Cultural interaction sometimes functions as a rotten apple and sometimes provides a negative exemplar of how not to behave.

Keywords

Artistic explosion • Cultural evolution • Cumulative culture • Neanderthals

17.1 Introduction

To investigate the replacement of Neanderthals (and other archaic humans) by modern humans (*Homo sapiens*), we must consider the differences between the Paleolithic cultures of both species. Before the emergence of modern humans, cultural evolutionary rates were extremely low. The Acheulean tradition of *Homo erectus* remained much the same in the archaeological record for over a million years, which is described as a period of "unimaginable monotony" (Jelinek 1977; but see Beyene et al. 2013, who shows temporal changes of Acheulean tradition), and the Mousterian tradition of Neanderthals was almost static for hundreds of thousands of years (Akazawa et al. 1998). On the other hand, modern human culture changed frequently during and after the Upper Paleolithic in Europe (Bar-Yosef 2002) and the Middle Stone Age in Africa (McBrearty and Brooks 2000), although some researchers argue that cultural evolutionary rate did not speed up in the Middle Stone Age.

However, when we focus on the details of the transitional cultures in modern and archaic humans, the situation is not simple. The patterns of cultural changes in each region were various. Here, the transitional cultures are the cultures of the age when replacement of archaic humans by modern humans was taking place, and the carriers (makers) of them were both modern and archaic humans. The carriers of some cultural traditions are uncertain and controversial because of poor fossil evidence and layer admixture.

W. Nakahashi (✉)
Department of Human Biology and Anatomy, Graduate School of Medicine, University of the Ryukyus, Uehara 207, Nishihara-cho, Nakagami, Okinawa, 903-0215, Japan
e-mail: w.nakahashi@gmail.com

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_17, © Springer Japan 2013

In Africa, anatomically modern humans may have emerged around 200,000 years ago, which may be linked to the appearance of Middle Stone Age technology at 250,000–300,000 years ago (McBrearty and Brooks 2000). High level cultural traits appeared and disappeared iteratively in various regions before 85,000 years ago. Cultural evolution speeded up and various new cultural traits appeared after that time, but the speeds were different among regions.

In Europe, modern humans invaded about 45,000 years ago and rapidly spread over every region except south Iberia (reviewed in Mellars 2011). The artistic explosion of modern humans occurred soon after their invasion. That is, certain artistic behaviors of modern humans emerged first in Europe rather than Africa, and some researchers consider that the interaction with Neanderthals influenced these cultural innovations (Pike et al. 2012; reviewed in Balter 2012). On the other hand, late Neanderthals may have learned higher level cultural traits from modern humans (Hublin et al. 2012).

In Asia, small scale invasion of modern humans may possibly have occurred before 74,000 years ago (inland route) and around 60,000 years ago (coastal route), and large scale invasion occurred about 40,000–50,000 years ago (reviewed in Appenzeller 2012). Because of poor fossil evidence in Asia, how the dispersal of modern humans occurred is uncertain in this region compared with Europe. Cultural change was not drastic but gradual in Siberia and East Asia.

When we study these transitional cultures, we have to consider the effects of interactions between modern and archaic humans. Modern and archaic humans may have interbred (Shimada et al. 2007; Green et al. 2010; Reich et al. 2012; Meyer et al. 2012), suggesting that they also interacted culturally. Cultural change in late Neanderthals also suggests cultural interactions between Neanderthals and modern humans (Hublin et al. 2012). However, no previous mathematical models of cultural evolution have included cultural interactions between different groups that may have different learning abilities, although some studies considered structured populations (Lehmann et al. 2010; Kobayashi and Wakano 2012). This is partly because previous models place strong mathematical restrictions on the probability distribution of cultural trait values learned by each individual (Henrich 2004; Kobayashi and Aoki 2012). Therefore, I propose a new model that has no such restriction to deal with cultural interactions. Details of analysis will be shown elsewhere.

17.2 Model

Figure 17.1 describes the model. Cultural traits are expressed as real numbers, and every mature individual has one cultural trait (numbers in heads). A newborn learns cultural traits from multiple individuals in their parental generation. The number of exemplars from which each newborn learns is k ($k \geq 2$). All newborns have the same number of exemplars.

Next, he/she explores around each socially learned cultural trait symmetrically with dispersion φ^2. That is, when he/she learns from an exemplar with a cultural trait value z, the "explored" cultural traits are distributed with mean z and variance φ^2. Although in Fig. 17.1 the distribution of exploration is normal, this is a schematic figure and we do not assume a specific form for this distribution.

Then, he/she compares and judges the utility of the k explored cultural traits according to the following criterion to adopt his/her mature cultural trait. We consider weak directional selection (preference) so that cultural traits with larger value have slightly larger utility. The relative probability that he/she adopts a cultural trait z is assumed to be a linear function of the utility of cultural trait,

$$w(z) = 1 + az \tag{17.1}$$

where a is small. All individuals have the same criterion (preference).

Then, the expected mature cultural trait value of individual i is

$$E\left(z'_i\right) = \overline{z}_i + \frac{s_i^2 + \varphi^2}{1/a + \overline{z}_i} \tag{17.2}$$

where $\overline{z}_i$ and s_i^2 are the mean and variance of cultural trait values of his/her exemplars, which are assumed to be uncorrelated. Assuming further that exemplars are randomly chosen from the parental generation, we have $E\left(\overline{z}_i\right) = \overline{z}$ and $E\left(s_i^2\right) = \frac{k-1}{k}\sigma^2$, where $\overline{z}$ and σ^2 are the population mean and variance of the parental generation. Hence, the expected population mean in the offspring generation becomes

$$E\left(\overline{z}'\right) = \overline{z} + \frac{\sigma^2 (k-1)/k + \varphi^2}{1/a + \overline{z}} \tag{17.3}$$

provided selection (preference) is weak ($a\sigma << 1$). Therefore the generational change of mean cultural trait value in the population is

$$\Delta\overline{z} = E\left(\overline{z}'\right) - \overline{z} = \frac{\sigma^2 (k-1)/k + \varphi^2}{1/a + \overline{z}}, \tag{17.4}$$

which we define as cultural evolutionary speed. This equation implies that the population mean and variance of the parental generation affects the cultural evolutionary speed.

Let us next obtain the variance of the cultural trait value of the population at steady state. Assuming that preference is sufficiently weak, the variance increases due to exploration by each individual around the socially learned trait value, and it decreases due to the sampling

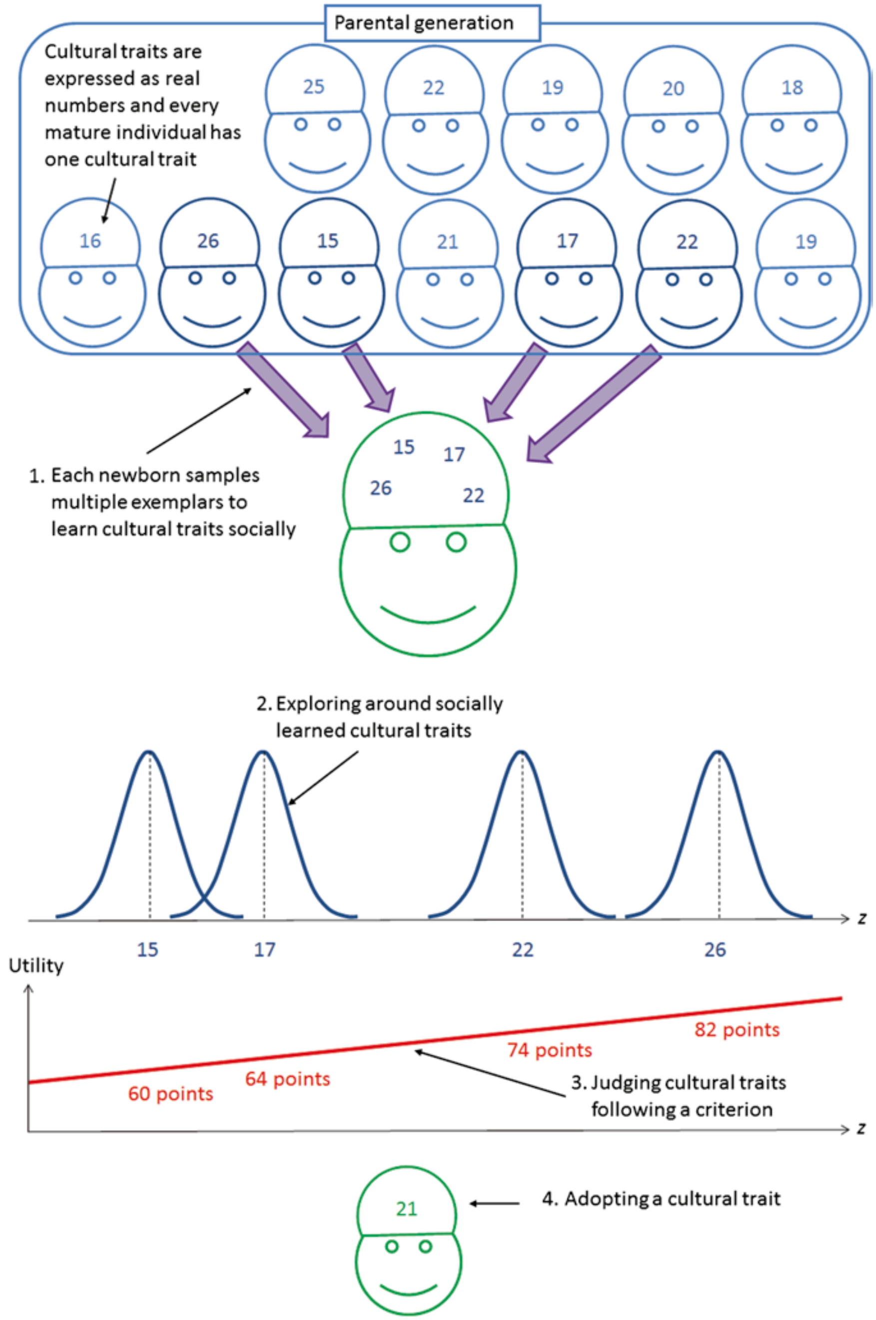


Fig. 17.1 The graphical explanation of the model

effect (it decreases to $(N-1)/N$ times its previous value where N is the population size). In addition, it may be realistic to assume that the variance also decreases due to a human social learning tendency that is not included in the above model. That is, humans tend to avoid adopting extreme cultural traits, which may reduce the cultural trait variance of the population. Although this tendency is often modeled as conformist transmission (preference for common cultural traits: Henrich and Boyd 1998; Nakahashi 2007; Wakano and Aoki 2007; Nakahashi et al. 2012), in this paper I model this by introducing the blending effect (preference for the mean cultural trait) proposed by Boyd and Richerson (1985). Since this effect may be far stronger than the sampling effect when population size is large, we neglect the sampling effect in the following.

Each individual sometimes (with probability q) blends socially learned cultural traits to adopt the weighted sample mean. Then the cultural trait variance of blenders is σ^2/k, so that the cultural trait variance becomes

$$\sigma^{2'} = q\frac{\sigma^2}{k} + (1-q)\left(\sigma^2 + \varphi^2\right). \tag{17.5}$$

Since $\hat{\sigma}^2 = \sigma^{2'} = \sigma^2$ at steady state, we have the steady state variance

$$\hat{\sigma}^2 = \frac{k}{k-1} \cdot \frac{1-q}{q} \varphi^2. \tag{17.6}$$

Substituting this into Eq. (17.4), we have the steady state cultural evolutionary speed

$$\Delta \bar{z} = \frac{1}{1/a + \bar{z}} \cdot \frac{\varphi^2}{q}. \tag{17.7}$$

Therefore, cultural evolutionary speed increases when the dispersion of exploration (φ^2) is large, the strength of preference for cultural traits (a) is large, and blending probability (q) is small. In other words, when individuals have higher creativity to explore a wider range of cultural traits, accurately judge the utility of cultural traits (strong direct bias), and do not strongly rely on the population mean, culture evolves faster. Hence, high creativity supported by individual learning ability can accelerate cultural evolution, which is analogous to Aoki et al. (2011) and Kobayashi and Aoki (2012).

This model is useful for evaluating other factors that may affect human cultural evolution. First, let us consider vertical transmission. In this case, if cultural traits are transmitted from both parents ($k=2$), the results do not change. However, if cultural traits are transmitted from one parent ($k=1$), Eq. (17.4) entails that $\Delta \bar{z} = \frac{\varphi^2}{1/a + \bar{z}}$, so that the population variance has no effect on the cultural evolutionary speed, and the speed is slower than for oblique transmission with $k \geq 2$.

Second, let us consider the effect of "relatedness". Although the above basic model assumes that each newborn randomly samples exemplars from the parental generation, he/she may sample exemplars with similar cultural trait values. For example, if the population is subdivided, each newborn tends to sample exemplars with similar cultural trait. Let the relatedness (correlation) of cultural trait values between two exemplars, j and h, be R; i.e., $R = \mathrm{Corr}(z_j, z_h)$ (Boyd and Richerson 1985). Then, the expected variance of cultural trait values of exemplars is

$$E\left(s_i^2\right) = \frac{k-1}{k}(1-R)\sigma^2. \tag{17.8}$$

The cultural trait variance of blenders is $\frac{1+R(k-1)}{k}\sigma^2$, so that the cultural trait variance becomes

$$\sigma^{2'} = q\frac{1+R(k-1)}{k}\sigma^2 + (1-q)\left(\sigma^2 + \varphi^2\right). \tag{17.9}$$

Thus, the steady state variance is

$$\hat{\sigma}^2 = \frac{1}{1-R} \cdot \frac{k}{k-1} \cdot \frac{1-q}{q} \varphi^2 \tag{17.10}$$

and the steady state cultural evolutionary speed is

$$\Delta \bar{z} = \frac{1}{1/a + \bar{z}} \cdot \frac{\varphi^2}{q}. \tag{17.11}$$

That is, relatedness does not affect the speed. This result suggests that we need not consider group structures when we study the cultural evolutionary speed at steady state, although the evolution of group structures in hominids is one of the key topics in anthropology (Nakahashi and Horiuchi 2012).

Third, let us consider the effect of one-to-many (teacher) transmission. Although the basic model assumes that every individual in the population can be chosen as an exemplar by the next generation, only certain individuals may in fact be an exemplar (teacher) in human society. Let the number of teachers be T. Provided the mean cultural trait value of teachers is the same as the population mean, this situation is the same as sampling from a teacher population with variance $\frac{T-1}{T}\sigma^2$. Then, the expected variance of cultural trait values of exemplars is

$$E\left(s_i^2\right) = \frac{k-1}{k} \cdot \frac{T-1}{T}\sigma^2, \tag{17.12}$$

so the cultural trait variance becomes

$$\sigma^{2'} = q\frac{T-1}{T} \cdot \frac{\sigma^2}{k} + (1-q)\left(\frac{T-1}{T}\sigma^2 + \varphi^2\right). \tag{17.13}$$

Thus, the steady state variance is

$$\hat{\sigma}^2 = \frac{Tk(1-q)}{k + (T-1)(k-1)q}\varphi^2 \tag{17.14}$$

and the steady state cultural evolutionary speed is

$$\Delta \bar{z} = \frac{1}{1/a + \bar{z}}\left(1 - \frac{(1-q)k}{k + (T-1)(k-1)q}\right)\frac{\varphi^2}{q}. \tag{17.15}$$

That is, the speed slightly decreases as the number of teacher decreases, but this effect is almost negligible when the number of teachers is large. If only a few charismas transmit cultural traits, the speed may change significantly, but such a situation may not have occurred in the Stone Age. So, one-to-many transmission does not essentially affect the speed of cultural evolution, a result which is in contrast to Lycett and Gowlett (2008) but consist with Aoki et al. (2011). However, this does not mean that the selection of teachers does not affect the speed. That is, if "specialists" tend to be selected as teachers (Pigeot 1990), they may have higher values of cultural trait, so cultural evolution may speed up. In this model, direct bias of selecting exemplars with better cultural traits (large a) strongly affects cultural evolutionary speed. In other words, the selection of teachers accelerates cultural evolutionary speed not by one-to-many transmission but by direct bias.

Fourth, let us consider the effect of condition dependent exploration. Although the basic model assumes that the width of exploration is constant under every condition, humans tend to explore wider when the cultural trait values of exemplars are distributed more widely. That is, we may not try many behaviors if exemplars have similar behaviors [e.g., the effect of unanimity (Asch 1955)] but may try many if they have various behaviors. Let the exploration variance be $rs_i^2+\varphi^2$ (instead of the constant φ^2 in the basic model). Then, the cultural trait variance becomes

$$\sigma^{2'} = q\frac{\sigma^2}{k} + (1-q)\left(\sigma^2 + r\frac{k-1}{k}\sigma^2 + \varphi^2\right). \qquad (17.16)$$

When $r > \frac{q}{1-q}$, the variance and cultural evolutionary speed increase to infinity. When $r < \frac{q}{1-q}$, the steady state variance is

$$\hat{\sigma}^2 = \frac{k}{k-1}\cdot\frac{1-q}{q-r(1-q)}\varphi^2 \qquad (17.17)$$

and the steady state cultural evolutionary speed is

$$\Delta\bar{z} = \frac{1}{1/a+\bar{z}}\cdot\frac{\varphi^2}{q-r(1-q)}. \qquad (17.18)$$

That is, when the width of exploration is strongly affected by the variance of exemplars' cultural traits, culture evolves fast.

Fifth, let us consider the error of social learning. Henrich (2004) and Kobayashi and Aoki (2012) assumed that the mode of socially learned behavior is smaller than that of exemplars because of the error of social learning. Including the error of social learning, ε, into the basic model, we have

$$E\left(\bar{z}'\right) = \bar{z} - \varepsilon + \frac{\sigma^2(k-1)/k+\varphi^2}{1/a+\bar{z}}. \qquad (17.19)$$

Since the change of variance is the same as the basic model, cultural evolutionary speed at steady state is

$$\Delta\bar{z} = \frac{1}{1/a+\bar{z}}\cdot\frac{\varphi^2}{q} - \varepsilon \qquad (17.20)$$

so that the cultural trait value converges to an equilibrium,

$$\hat{\bar{z}} = \frac{\varphi^2}{q\varepsilon} - \frac{1}{a}. \qquad (17.21)$$

That is, cultural level evolves higher when social learning ability is higher (ε is small). Moreover, high improvement ability (large φ^2 and a) brings about high level culture, which is analogous to Nakahashi (2013).

17.3 Interaction of Two Populations

The above models address the cultural evolution of one population. Here, we are interested in the cultural interactions of two (or more) populations. Since the model has no assumption on the distribution of cultural trait values (except the weak preference assumption), we can easily consider the situation that a population meets another population to interact culturally (but not genetically). Let us consider the situation where population M with mean $\bar{z}_M$ and variance σ_M^2 comes into contact with population A with mean $\bar{z}_A$ and variance σ_A^2. If a newborn of population M samples an exemplar from population A with probability p_M (strength of interaction), population M can be considered to have the "exemplar population" with mean $(1-p_M)\bar{z}_M + p_M\bar{z}_A$ and variance $(1-p_M)\sigma_M^2 + p_M\sigma_A^2 + p_M(1-p_M)(\bar{z}_M-\bar{z}_A)^2$. Similar considerations apply to population A. By setting other parameters as in Fig. 17.2, we can easily trace the generational changes of mean and variance of cultural traits values of populations M and A as follows.

$$\bar{z}_M' = (1-p_M)\bar{z}_M + p_M\bar{z}_A + \frac{\left[(1-p_M)\sigma_M^2 + p_M\sigma_A^2 + p_M(1-p_M)(\bar{z}_M-\bar{z}_A)^2\right](k_M-1)/k_M + \varphi_M^2}{1/a_M + (1-p_M)\bar{z}_M + p_M\bar{z}_A} \qquad (17.22)$$

$$\sigma_M^{2\prime} = (q_M/k_M + 1 - q_M)\left[(1-p_M)\sigma_M^2 + p_M\sigma_A^2 + p_M(1-p_M)(\bar{z}_M-\bar{z}_A)^2\right] + (1-q_M)\varphi_M^2 \qquad (17.23)$$

$$\bar{z}_A' = (1-p_A)\bar{z}_A + p_A\bar{z}_M + \frac{\left[(1-p_A)\sigma_A^2 + p_A\sigma_M^2 + p_A(1-p_A)(\bar{z}_M-\bar{z}_A)^2\right](k_A-1)/k_A + \varphi_A^2}{1/a_A + (1-p_A)\bar{z}_A + p_A\bar{z}_M} \qquad (17.24)$$

$$\sigma_A^{2\prime} = (q_A/k_A + 1 - q_A)\left[(1-p_A)\sigma_A^2 + p_A\sigma_M^2 + p_A(1-p_A)(\bar{z}_M-\bar{z}_A)^2\right] + (1-q_A)\varphi_A^2 \qquad (17.25)$$

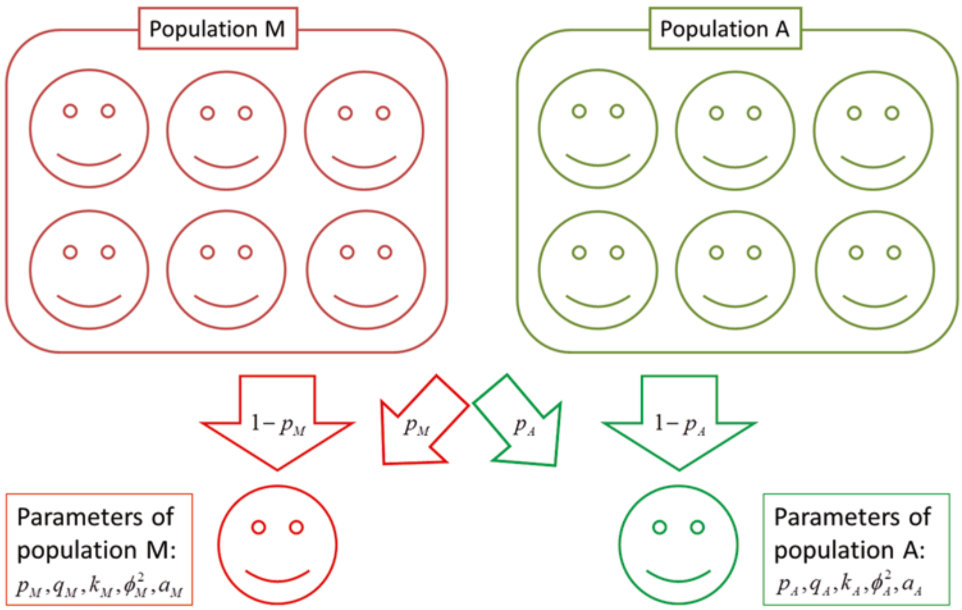


Fig. 17.2 Cultural interaction of two populations

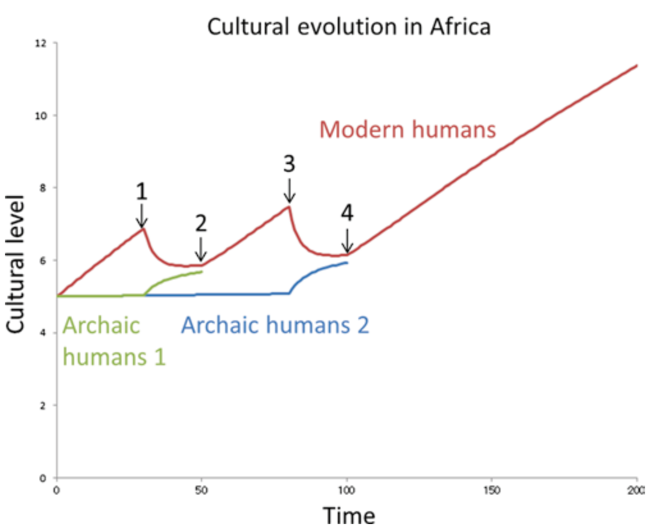


Fig. 17.3 The scenario of cultural evolution in Africa. Event 1: Beginning of interaction with archaic humans 1. Event 2: Extinction of archaic humans 1. Event 3: Beginning of interaction with archaic humans 2. Event 4: Extinction of archaic humans 2

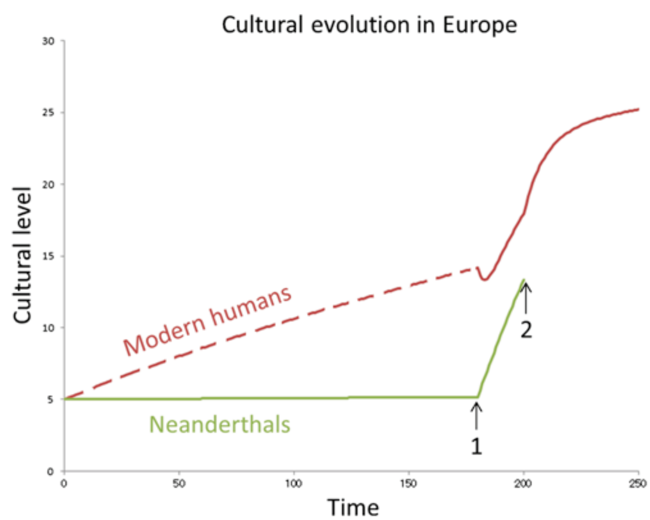


Fig. 17.4 The scenario of cultural evolution in Europe. Event 1: Invasion of modern humans. Event 2: Extinction of Neanderthals

I simulated some situations of cultural interactions between modern and archaic humans (Figs. 17.3, 17.4, and 17.5). In these simulations I assumed that modern humans had higher learning abilities than archaic humans ($a_M > a_A$, $\varphi_M^2 > \varphi_A^2$) and genetic admixture did not occur. Details are explained in Discussion of this paper, so here I focus on one interesting mathematical problem. In Fig. 17.4, cultural evolution of modern humans can be seen to speed up after the interaction with archaic humans. Under what conditions does cultural interaction bring about such "explosion" of culture?

In order to consider this problem mathematically, we assume for simplicity that initial cultural trait variances of populations M and A are the same, cultural interaction occurs only once (one generation), and preference is sufficiently small. Also, we delete subscript M from all parameters of population M. Then, writing the initial mean cultural trait value of population A as $\bar{z} - g$, population M has the "exemplar population" with mean $\bar{z} - pg$ and variance $\sigma^2 + p(1-p)g^2$. Under what conditions can the cultural level of this population exceed that of a non-interacting population that has the exemplar population with mean $\bar{z}$ and variance σ^2?

Assume that $\frac{1}{1/a+\bar{z}} \approx a$ always holds (weak preference). Then, since the difference in variances between the interacting and non-interacting populations is $p(1-p)g^2$, from Eqs. (17.4) and (17.22), the increase of cultural level by preference in the interacting population is

$$\frac{p(1-p)g^2(k-1)/k}{1/a+\bar{z}} \approx ap(1-p)g^2 \cdot \frac{k-1}{k} \qquad (17.26)$$

which is larger than in the non-interacting population. From Eqs. (17.5) and (17.23), in the next generation, the difference in variances between the interacting and non-interacting populations decreases to

$$\left(1-q+\frac{q}{k}\right)p(1-p)g^2. \qquad (17.27)$$

Finally, total increase of cultural level by preference in the interacting population is

$$ap(1-p)g^2 \cdot \frac{k-1}{k} \cdot \sum_{i=0}^{\infty}\left(1-q+\frac{q}{k}\right)^i = \frac{ap(1-p)g^2}{q} \qquad (17.28)$$

which is larger than that in the non-interacting population. This exceeds the difference of the mean cultural trait values of exemplar populations at the first generation, pg, when

$$a(1-p)g > q. \qquad (17.29)$$

In other words, mean cultural level of interacting population ultimately exceeds that of non-interacting population when Eq. (17.29) holds. So, explosion of culture occurs when the difference in cultural level between modern and archaic population (g) is large, the strength of interaction (p) is small, the tendency of blending (q) is small, and the preference (a) is strong. Although this condition does not satisfy the weak preference assumption $ag<<1$, individual based simulations (not shown in this paper) suggest explosion of culture may occur.

17.4 Discussion

In this paper, I have studied the factors that affect cultural evolutionary speed. I have shown that cultural evolutionary speed increases when individuals have higher creativity to explore a wider range of cultural traits, accurately judge the utility of cultural traits (strong direct bias), do not strongly rely on the population mean, increase the exploration range when the variance of socially learned cultural traits is large (condition dependent exploration), and make smaller error in social learning. The number of exemplars, population size, relatedness (similarity) of exemplars' cultural traits, and one-to-many (teacher) transmission have little effect on cultural evolutionary speed. In other words, cultural evolutionary speed is mainly accelerated by high learning abilities. Although this result depends on some model assumptions, learning abilities are the main factors that determine cultural evolutionary speed provided the difference among the utilities of cultural traits is small (weak preference) and population size is large (when population size is very small, population size and the number of acquaintances affect cultural evolutionary speed; not shown in this paper).

This result is different from the claim made by previous studies that population size and the number of acquaintances strongly affect cultural evolutionary speed (Henrich 2004; Kobayashi and Aoki 2012). This is because, in their models, individuals always learn from an exemplar with the best cultural trait they observe. Therefore, the selection (preference) is extremely strong, which is different from my model assumption. In a situation where the utilities of behaviors (cultural traits) are clear and everyone can recognize the best behavior, their model is appropriate. However, in the real world, the utilities of many behaviors are unclear. Many behaviors are sometimes beneficial but sometimes useless, so it is difficult to identify the best behavior. In such a situation, we may avoid learning extreme cultural traits and depend on the sample mean. My model is realistic in this situation. Therefore, we can consider that population size and the number of acquaintances affect cultural evolutionary speed only when the utilities of cultural traits are clear (or population size is very small).

Next, I have considered the situation where two species (e.g., modern and archaic humans) interact culturally. I have shown that explosion of culture occurs when the difference in cultural level between two populations is large, the interaction is weak, the tendency of blending is small, and the preference is relatively strong. In other words, when a newborn observes a few individuals with extremely low level culture, they function as a "negative exemplar" of how not to behave. On the other hand, when a newborn observes many individuals with slightly low level culture, they function as a "rotten apple" to decrease cultural level. These results can intuitively be explained as follows. When the difference is small, it is difficult to judge utilities of cultural traits so that exposure to low level culture entails the decrease of cultural level. When the difference is large, we can easily judge utilities of cultural traits so that we can increase cultural level by avoiding the inferior cultural traits and adopting the better ones.

I numerically simulated some situations of cultural interactions between modern and archaic humans (Figs. 17.3, 17.4, and 17.5). In these simulations I assumed that modern humans had higher learning abilities than archaic humans and genetic admixture did not occur. Figure 17.3 shows the scenario of cultural evolution in Africa. At a certain time

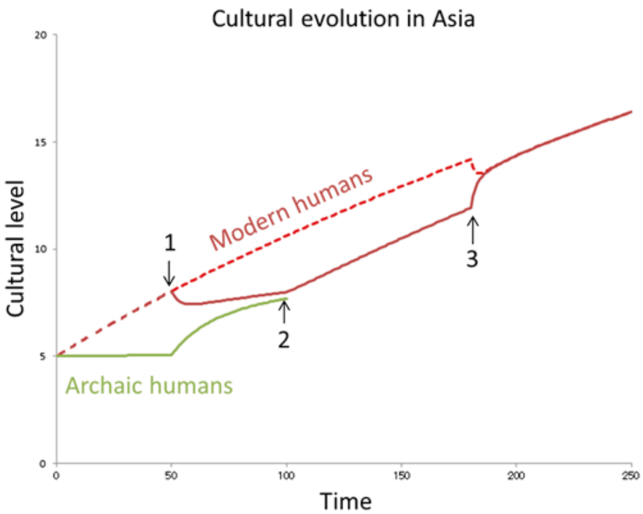


Fig. 17.5 The scenario of cultural evolution in Asia. Event 1: First wave invasion. Event 2. Extinction of archaic humans. Event 3: Large-scale invasion

(time 0) modern humans with higher individual learning abilities appeared. In this paper, I do not discuss why higher learning abilities evolved only in modern humans (this problem is discussed in Nakahashi 2010, 2013). Because of higher learning abilities, cultural level of this modern human population evolved to exceed that of other archaic populations with lower abilities. However, cultural interaction with archaic populations began as the modern population expanded, which caused contamination of the modern population by low level culture. This may have functioned as the rotten apple so that cultural level decreased. Such interaction may have occurred several times, which resulted in iterative appearances and disappearances of high level culture in Africa. After almost all archaic humans in Africa went extinct, cultural evolution of modern humans speeded up. Some researchers argue that cultural evolutionary speed of modern humans in the Middle Stone Age in Africa was not significantly different from that of Neanderthals. My simulations suggest that, even if modern human learning abilities improved in early Middle Stone Age, their cultural evolutionary speed may have not increased significantly for a long time because of cultural interactions with African archaic populations with lower learning abilities. In fact, Shea (2011) argued that behavioral variability of the oldest *Homo sapiens* was almost the same as that of present-day humans. Moreover, the oldest evidence for "modern behavior" (although this concept is frequently criticized) in Africa is dated to before 100,000 years ago (McBrearty 2012), but that in Europe is dated around 50,000 years ago (Pike et al. 2012; Zilhão et al. 2010), suggesting that early modern humans may have had higher learning abilities than Neanderthals.

Figure 17.4 shows the scenario of cultural evolution in Europe. Since modern humans invaded Europe at a relatively late age, their cultural level may have already been high when they invaded Europe. Therefore, the difference in cultural level between Neanderthals and modern humans may have been large when modern humans invaded Europe. Then, Neanderthal culture may have functioned as the negative exemplar of how not to behave. Because of this effect, cultural level of modern humans in Europe evolved higher than that in other regions where modern humans did not interact with Neanderthals. In other words, cultural interaction with Neanderthals may have caused cultural explosion of European modern humans. Moreover, cultural interaction with modern humans may have resulted in the evolution of high level culture, such as Châtelperronian, in late Neanderthals.

Figure 17.5 shows the scenario of cultural evolution in Asia. First wave invasion of modern humans occurred when their cultural level was still low, so that cultural interaction with archaic humans may have functioned as the rotten apple. When large scale invasion of modern humans with higher cultural level occurred, they may have interacted with descendants of first wave modern human population, so that the difference in cultural level may not have been large. Therefore, this interaction also functioned as the rotten apple, so drastic cultural change did not occur. In other words, intermittent invasions of modern humans brought about the gradual cultural change in Asia.

Although these scenarios of cultural evolution in each region may oversimplify the real situation, it is important to take cultural interactions with archaic humans into consideration when we study transitional cultures. This mathematical model suggests that cultural interaction can function as both the rotten apple and the negative exemplar. I have obtained the condition for cultural interaction to function as the negative exemplar. I have shown that when modern humans experienced a limited amount of interaction with archaic humans with far lower level culture, the cultural interaction could function as the negative exemplar. Although some researchers consider that the increase of the tension between Neanderthals and modern humans caused the artistic explosion in Europe, this model suggests that this is unnecessary provided Neanderthal cultural level was low and the cultural interaction was weak. In fact, if we consider that the increased tension caused the explosion, it is difficult to explain why the cultural explosion occurred in art, not in weapons or something useful for competition. Moreover, since population size of Neanderthals may have been small compared with modern humans (Mellars and French 2011), the tension may not have been strong and the interaction may have been weak. Small amount of interbreeding between Neanderthals and modern humans in Europe from genetic evidence (Green et al. 2010) also suggests weak interaction between both species.

Before the invasion of modern humans into Europe, Neanderthals had almost no artistic materials in their culture. Therefore, cultural difference in art was very large between Neanderthals and modern humans, so Neanderthals may have functioned as the negative exemplar to cause the artistic explosion of modern humans.

This new view of the causes of the artistic explosion suggests that there was no special relationship between Neanderthals and modern humans. In fact, there is little evidence that the tension between European Neanderthals and modern humans was stronger than that in other regions. By considering different dispersal processes of modern humans into each region and cultural interactions between modern and archaic humans, we can explain the different patterns of cultural change in transitional cultures. From the principle of parsimony, we should not consider special reasons for the cultural changes of each region, but should apply the general mechanism of cultural evolution to them.

In conclusion, the present model can explain the different patterns of cultural change in African, European, and Asian transitional cultures invoking only the different dispersal processes of modern humans into each region and cultural interactions between modern and archaic humans. In Africa and Asia, cultural interactions between modern and archaic humans may have functioned as the rotten apple, and in Europe, as the negative exemplar. Weak interaction and large cultural difference causes the explosion of culture, and cultural interaction between modern humans and Neanderthals may have satisfied this condition.

References

Akazawa T, Aoki K, Bar-Yosef O (1998) Neandertals and modern humans in western Asia. Plenum, New York

Aoki K, Lehmann L, Feldman MW (2011) Rates of cultural change and patterns of cultural accumulation in stochastic models of social transmission. Theor Popul Biol 79:192–202

Appenzeller T (2012) Eastern Odyssey. Nature 485:24–26

Asch SE (1955) Opinions and social pressure. Sci Am 193:31–35

Balter M (2012) Early dates for artistic Europeans. Science 336:1086–1087

Bar-Yosef O (2002) The Upper Paleolithic revolution. Annu Rev Anthropol 31:363–393

Beyene Y, Katoh S, WoldeGabriel G et al (2013) The characteristics and chronology of the earliest Acheulean at Konso, Ethiopia. Proc Natl Acad Sci U S A 110:1584–1591

Boyd R, Richerson PJ (1985) Culture and the evolutionary process. University of Chicago Press, Chicago

Green RE, Krause J, Briggs AW et al (2010) A draft sequence of the Neandertal Genome. Science 328:710–722

Henrich J (2004) Demography and cultural evolution: how adaptive cultural processes can produce maladaptive losses-the Tasmanian case. Am Antiquity 69:197–214

Henrich J, Boyd R (1998) The evolution of conformist transmission and the emergence of between-group differences. Evol Hum Behav 19:215–241

Hublin JJ, Talamo S, Julien M et al (2012) Radiocarbon dates from the Grotte du Renne and Saint-Césaire support a Neandertal origin for the Châtelperronian. Proc Natl Acad Sci U S A 109:18743–18748

Jelinek AJ (1977) The Lower Paleolithic: current evidence and interpretations. Annu Rev Anthropol 6:11–32

Kobayashi Y, Aoki K (2012) Innovativeness, population size and cumulative cultural evolution. Theor Popul Biol 82:38–47

Kobayashi Y, Wakano JY (2012) Evolution of social versus individual learning in an infinite island model. Evol 66:1624–1635

Lehmann L, Feldman MW, Kaeuffer R (2010) Cumulative cultural dynamics and the coevolution of cultural innovation and transmission: an ESS model for panmictic and structured populations. J Evol Biol 23:2356–2369

Lycett SJ, Gowlett AJ (2008) On questions surrounding the Acheulean tradition. World Archaeol 40:295–315

McBrearty S (2012) Sharpening the mind. Nature 491:531–532

McBrearty S, Brooks A (2000) The revolution that wasn't: a new interpretation of the origin of modern human behavior. J Hum Evol 39:453–563

Mellars P (2011) The earliest modern humans in Europe. Nature 479:483–485

Mellars P, French JC (2011) Tenfold population increase in Western Europe at the Neandertal-to-modern human transition. Science 333:623–627

Meyer M, Kircher M, Gansauge MT et al (2012) A high-coverage genome sequence from an archaic denisovan individual. Science 338:222–226

Nakahashi W (2007) The evolution of conformist transmission in social learning when the environment changes periodically. Theor Popul Biol 72:52–66

Nakahashi W (2010) Evolution of learning capacities and learning levels. Theor Popul Biol 78:211–224

Nakahashi W (2013) Evolution of improvement and cumulative culture. Theor Popul Biol 83:30–38

Nakahashi W, Horiuchi S (2012) Evolution of ape and human mating systems. J Theor Biol 296:56–64

Nakahashi W, Wakano JY, Henrich J (2012) Adaptive social learning strategies in temporally and spatially varying environments. Human Nature 23:386–418

Pigeot N (1990) Technical and social actors flintknapping specialists and apprentices at Magdalenian Etiolles. Archaeol Rev Cam 9:126–141

Pike AWG, Hoffmann DL, García-Diez M et al (2012) U-series dating of Paleolithic Art in 11 Caves in Spain. Science 336:1409–1413

Reich D, Green RE, Kircher M et al (2012) Genetic history of an archaic hominin group from Denisova Cave in Siberia. Nature 468:1053–1060

Shea JJ (2011) *Homo sapiens* is as *Homo sapiens* was. Curr Anthropol 52:1–35

Shimada MK, Panchapakesan K, Tishkoff SA, Nato AQ Jr, Hey J (2007) Divergent haplotypes and human history as revealed in a worldwide survey of x-linked DNA sequence variation. Mol Biol Evol 24:687–698

Wakano JY, Aoki K (2007) Do social learning and conformist bias coevolve? Henrich and Boyd revisited. Theor Popul Biol 72:504–512

Zilhão J, Angelucci DE, Badal-García E et al (2010) Symbolic use of marine shells and mineral pigments by Iberian Neandertals. Proc Natl Acad Sci U S A 107:1023–1028

18 A Perspective on Evolutionary Models of Learning Strategies

Joe Yuichiro Wakano

Abstract

Many theoretical works using mathematical models or computer simulations have been performed. Although these studies have yielded some important achievements in theoretical aspects of evolution of learning strategies, they are described in mathematics and are not necessarily easily accessible to all empirical researchers. To facilitate more collaboration, here we verbally, without equations, review the simplest type of models of cultural evolution to acquaint empirical researchers with the common motivations of and questions asked by theoretical researchers in this field. Then we evaluate the assumptions of the simplest type of models in detail. This reviewing process might serve to make explicit the motivations or interests which have been considered as important by empirical researchers but never modeled by theoretical researchers.

Keywords

Cultural evolution • Mathematical models • Social learning and individual learning

18.1 Introduction

Since pioneering studies in 1980s (Lumsden and Wilson 1981; Feldman and Cavalli-Sforza 1984; Boyd and Richerson 1985; Rogers 1988), many theoretical works using mathematical models or computer simulations have been performed (cited later). At the same time, there exists increasing interest in evolution of learning strategies among empirical researchers in archaeology, anthropology, and psychology. However, some important achievements in theoretical aspects of evolution of learning strategies are described in mathematics, which is not necessarily easily accessible to all empirical researchers. To facilitate more collaboration between theoretical and empirical researchers in future, it is important to share the motivation of study. Here we verbally review the simplest type of evolutionary models of learning strategies to introduce the common motivations and questions among theoretical researchers in this field. Then we evaluate the assumptions of the simplest type of models. Assumptions in models are adopted for simplification. Simplification is performed not only for mathematical tractability, but also to illuminate what is considered as important. Looking at typical assumptions of models, we can infer what theoreticians have considered more important and what theoreticians have considered less important. Theoreticians' interests are not necessarily the same as those held by empirical researchers. Although here we can only introduce some typical motivations, since different theoreticians have different motivations, we hope that this short communication can help us to find motivations or interests which have been considered as important by empirical researchers but have never (or rarely) been modeled by theoretical researchers.

J.Y. Wakano (✉)
Organization for the Strategic Coordination of Research and Intellectual Property, School of Interdisciplinary Mathematical Sciences, Meiji University,
4-21-1 Nakano, Nakano-ku, Tokyo 164-8525, Japan
e-mail: joe@meiji.ac.jp

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8_18,

18.2 A Verbal Review of the Simplest Type of Models of IL and SL

In this section, we verbally review mathematical models of learning strategies (see Aoki and Feldman in press for a more detailed review with equations). Particularly, we verbally explain the simplest type of models in detail (based on a model proposed by Feldman et al. 1996; see also Rogers 1988). Recent theoretical studies on evolution of learning strategies are more or less the extensions of this type of models. Here we try to describe typical basic ideas that theoreticians in this field have in mind.

The learning process in human is obviously very complex, and there might be different opinions on how to classify it into few types. In most theoretical studies, learning is classified into two types; individual learning (IL) and social learning (SL). In this classification, IL is the learning process where social interaction does not play any role, e.g. trial-and-error learning. On the other hand, SL is the learning process in which social interaction is necessary, e.g. copying, teaching or imitation.

The simplest type of models assumes that an individual chooses one of the two strategies. If an individual chooses the IL strategy, she only performs IL throughout her life. If an individual chooses the SL strategy, she only performs SL throughout her life. This assumption allows us to refer to the SL (resp. IL) strategy as SL (resp. IL), and we do so only when we describe the simplest type of models. It also assumes only two types of behaviors, namely Correct and Wrong. Both learning strategies aim to achieve a higher chance of acquiring the Correct behavior. For example, IL relies on trial-and-error, while SL relies on copying another individual's behavior. Despite this extreme simplification, these models raise some interesting questions. One of the most frequently asked questions is whether the SL strategy can be adaptive. If an individual copies the behavior of a randomly chosen individual, it might seem that the SL strategy does not help to acquire Correct. However, if individuals with Correct behavior are more adaptive (e.g., higher survival rate) and hence the frequency of Correct among individuals in the population is greater than one-half, a random choice from behaviors of other individuals gives a higher chance of acquiring Correct than a random choice between Correct and Wrong. The frequency of Correct determines which of the IL and SL strategies is superior.

To understand the ultimate factor of a certain behavior of animals, theoretical biologists use the framework of evolutionary game theory. In this framework, we hypothesize alternative strategies, calculate fitness of each strategy, and obtain the strategy that will finally dominate after a sufficient number of generations. Many theoretical studies on evolution of learning strategy apply this framework. More precisely, we assume discrete generations and the following life history.

1. A child genetically inherits the parent's strategy (IL/SL), but not the behavior.
2. A child performs IL or SL only once in life time, to acquire the Correct or Wrong behavior. A child having the SL strategy copies the behavior of a randomly chosen individual in the parental generation (oblique transmission). A child having the IL strategy acquires the Correct behavior with a given fixed probability and the Wrong behavior with the complementary probability.
3. Based on their behavior (Correct/Wrong) and on their strategy (IL/SL), their fitnesses are determined. Different exogenous costs to different strategies of learning are assumed. According to the fitness values, some children die (viability selection).
4. Children mature and form the next generation. Parents die.

With this life history assumption, the dynamics of the frequency of the strategies can be calculated for as many generations as we like. Thus we can calculate whether the IL or SL strategy dominates after a sufficient number of generations.

As long as the same behavior is Correct in all generations, the frequency of Correct keeps increasing. Why? Recall that the behavior itself is not directly inherited. A child of a Correct individual does not necessarily acquire Correct. So it is not because Correct produces more offspring. The reason is that Correct is more likely to be copied by SL, because Wrong decreases at viability selection (stage 3 in the life history described above). If the frequency of Correct is 70 % in the parental generation, SL children learn Correct with a probability 70 %, but those who learned Correct are more likely to survive. Thus, after viability selection, the frequency of Correct is larger than 70 %. It is SL, not IL, that changes the frequency of Correct. As the Correct behavior becomes more and more common, the SL strategy finally dominates.

If we assume changing environment such that Correct (resp., Wrong) is not always Correct (resp., Wrong) in the next generation, there might exist a considerable frequency of Wrong even after many generations. For the IL strategy, environmental change between generations does not alter performance because trial-and-error is performed in the new environment. On the other hand, for the SL strategy, it matters a lot, because it can no longer be expected that the behavior that is Correct in her own generation has a frequency of greater than one-half in the parental generation. With environmental change, it becomes an interesting question whether IL or SL dominates.

18.2.1 Results of the Simplest Type of Models of IL and SL

The simplest type of models has been studied in detail. There exist several variations with respect to mathematical formulations, but we have some qualitative results that have been repeatedly confirmed irrespective of the mathematical details.

First, when environmental change is sufficiently frequent, neither the IL nor SL strategy dominates. Instead, the coexistence of IL and SL lasts forever, i.e., some individuals only perform IL and some only perform SL but as a population we observe a mixture of IL and SL. The result can be intuitively understood if we think of the extreme case when the environment changes every generation. Then copying the majority behavior in parental generations has no merit and the SL strategy cannot be adaptive. If the environment is stable, there exists a positive correlation between the success (survival) of an individual and whether the behavior of the individual is still Correct in the next generation. This correlation represents the advantage of SL over a random choice between Correct and Wrong. If the correlation is stronger than the probability of acquiring Correct by IL, SL is the adaptive strategy.

Second, when coexistence of IL and SL occurs, the performance of a population (e.g., the average frequency of Correct) does not exceed that of the IL-only population. This means that, although SL ability is given as an alternative strategy, there is no merit from the viewpoint of the optimization of the population-level performance. This is known as Rogers' paradox. This result can also be intuitively explained by the correlation. If the correlation is strong so that SL is more adaptive than IL, then the SL frequency increases and the IL frequency decreases. This means that the number of independent sources of information on the environment decreases. Thus, on average, people's behavior becomes closer to a random choice, which entails a decrease in the correlation, which weakens the advantage of SL. Thus, we expect a stable coexistence of IL and SL at the ratio where the correlation (the benefit of SL) balances the benefit of IL.

18.3 Reconsidering the Assumptions of Typical Models

Many assumptions are explicitly or implicitly imposed in the simplest type of models. Here we summarize some of them. Note that many of them have been partly or fully relaxed in recent studies. (However, the combined effect of relaxing these assumptions is almost impossible to predict.) Note also that the author does not intend to criticize the simplest type of models in any sense.

18.3.1 Individual Learning

Many animal species are known to have some ability of learning. Trial-and-error or reinforcement learning has been studied for many years in psychology and other areas. It is natural to consider that human has a qualitatively different type of learning ability, e.g. creativity. This seems to be an important topic in the study of human cultural evolution, but few modeling papers distinguish trial-and-error learning and creativity, presumably because of the lack of a clear definition of creativity (Lehmann and Wakano 2013).

18.3.2 Social Learning

In addition to social learning from individuals in the parental generation (oblique SL), humans perform SL from individuals in the same generation (horizontal SL). Human SL is not just a simple and random copying. We choose who to learn from. We learn from someone who looks successful (payoff-biased transmission) or someone who has a higher social influence (prestige-biased transmission). We might tend to learn the behavior which has the largest frequency (conformism). These kinds of variations of SL are relatively studied well in theoretical studies (e.g., Henrich and Boyd 1998; Wakano and Aoki 2007; Nakahashi et al. 2012).

18.3.3 Behavior, Information, or Meme

In reality, there exist many types of behaviors that can be culturally transmitted, certainly more than Correct and Wrong. The Correct/Wrong assumption is adopted not only for mathematical simplicity. If we have only two behaviors, we can understand the results of models more easily. A conceptual assumption underlying the simplest type of models is that fitness of behavior is only determined by Environment-Behavior matching. In principle, it is assumed that learning is performed to keep updated in changing environment. However, Environment-Behavior matching is merely one example of the utility of behavior. Behavior (e.g., stone-tools) can be improved even in a constant environment. The improvement of tools through cultural evolution could be a virtually endless process and modern human culture does not actually appear to be at stasis. We have fewer theoretical models dealing with endless improvement, presumably because the common mathematical technique relies on the existence of equilibrium in cultural dynamics (but see Henrich 2004; Kobayashi and Aoki 2012).

18.3.4 Social Structure

Obviously, human society is neither homogenous nor well-mixed. For example, human population consists of individuals of different ages who play age-dependent roles in society. Social interactions often take place in local social networks. Division of labor might also be important especially in the later phases of human evolution including the replacement of Neanderthals by *sapiens*. Spatiotemporal dynamics of IL and SL are also relevant to study the range-expansions including out-of-Africa. Several theoretical studies have already been performed in this perspective (Aoki and Nakahashi 2008; Lehmann et al. 2010; Rendell et al. 2010; Wakano et al. 2011; Kobayashi and Wakano 2012), but theory is not mature partly because of mathematical difficulty in the analysis of models with social structure.

18.3.5 More Realistic Learning Strategy

Empirical and also theoretical studies on human learning strategies have been performed in psychology (e.g., Izquierdo and Izquierdo 2008). Kameda and Nakanishi (2002) has performed an experiment in which subjects play a computer game called "Where is the rabbit?" In this game, participants judged in which of two nests a rabbit was currently located. A rabbit (=environment) had a tendency to stay in the same nest over time, but this tendency was not perfect. Thus, social learning gives better guess than random choice, but not perfect. Alternatively, participants can choose to perform individual learning by using a "rabbit-search-machine" at a cost. Kameda and Nakanishi (2002) referred to individual learning as "information-producer" and social learning as "information-scrounger." They observed polymorphism of the two strategies. Their experiment grasps the essence of what has been studied by the simplest type of models.

In ecology, the evolution of learning has been studied in the context of foraging. A well known example is found in waggle dance (figure-of-eight dance) of honeybees. Biesmeijer and Seeley (2005) has reported that younger bees are more likely to rely on SL (i.e., learning the location of a food site by watching dance) and that elder bees are more likely to rely on IL (i.e., searching a new food site on their own).

Compared to these empirical studies, the learning strategy assumed in the simplest type of models is very simplified and abstract. For mathematical simplicity, it is assumed that an individual can choose among only two strategies once in life: pure IL and pure SL. Relaxing this assumption to allow mixed strategies so that an individual performs IL with a certain probability and SL with the complementary probability is not mathematically very difficult, and there exist many studies (e.g., Wakano and Aoki 2006). A more conceptually challenging extension is to allow individuals to use IL and SL depending on the situation. Another important extension is to give individuals multiple rounds of learning. Combined with age-structure of society, this will yield a model of schedule of learning, in which individuals of different ages rely on IL or SL differently. Advances in basic theory of learning models have allowed us to analyze this type of models only recently (Aoki et al. 2012; Lehmann et al. 2013). On the other hand, agent-based simulation studies that can deal with more complicated learning strategies are also being studied (e.g., Arbilly et al. 2010).

18.3.6 Cumulative Cultural Evolution

In human evolution, innovation of stone tools might have played an important role. Advanced and complex lithic industries can never be invented by a single individual without learning from other individuals. They are results of cumulative cultural evolution in which knowledge is inherited from parental generations to offspring generations. However, if all individuals simply copy what is already known, there would be no advancement in technology. Contribution to the culture by improving the preceding knowledge, such as a discovery of new adaptive use or form of stone tools, is also crucial for cultural evolution. Inheritance of culture is realized by social learning and improvement is realized by individual learning. The simplest type of models assumes only one round of learning, so it is impossible to add some improvement on what has been socially learned. If we consider a model allowing multiple rounds of learning, cumulative cultural evolution is expected only when SL and IL are performed in this order (Enquist et al. 2007; Borenstein et al. 2008; Aoki 2010). There exist several theoretical studies in this perspective, and Aoki et al. (2012) has shown that the order of SL-then-IL is the adaptive strategy.

18.3.7 Optimization at Individual-Level or Group-Level

When we look for the adaptive strategy in a modeling framework, we frequently use standard evolutionary game theory that assumes a well-mixed population where all individuals are competing with each other. This means that an individual tries to reproduce more than other individuals although they exchange information through SL. In short, many simple models assume SL among hostile individuals. In reality, it seems that social partners with whom an individual often socially communicate are also those who often cooperate with each other. A good example is the interaction between mates. In this case, two individuals greatly share the reproductive success. Human band is also a unit of society in which the members often cooperate and socially interact at the same time. In such cases, the adaptive strategy is not the strategy that maximizes reproductive success at the individual-level, but rather reproductive success at group-level also counts. Wakano and Miura (2013) have shown that optimizations at individual-level and at group-level yield very different outcomes. Technically speaking, Technically speaking, selection gradient consists of selection within a group and selection between groups. The full analysis of such case is difficult, but is already well known in the theories of genetic evolution. Application of these theories to the field of cultural evolution has been initiated recently and many questions are still open (Lehmann et al. 2010; Kobayashi and Wakano 2012).

18.4 Discussion

As we have described so far, many models assume some sets of learning strategies and look for the best strategy among them. The choice of a set of strategies is arbitrary and it reflects the motivation of the researcher. Models also impose many assumptions that determine how different learning strategies interact with each other. These assumptions ultimately determine the fitness of each strategy in a frequency-dependent manner. There exist as many different types of models as the number of different motivations that researchers can have.

We have considered several assumptions in the simplest type of models. There may be more assumptions which are implicitly adopted because such assumptions are widely used by theoretical researchers. However, some such assumptions might be unnatural or even contradict basic premises in different areas of research. The search for such implicit assumptions might trigger an essentially new theory of cultural evolution. In this sense, the assumptions that are explicitly described here are those that theoreticians have already recognized and begun to investigate the consequences of relaxing them, and hence they might be less important.

I would like to emphasize that this communication is not a full review paper, so the citations are just examples. Finally, I would like to emphasize that there might exist very different kinds of models of learning in other fields including economics and optimal foraging theory and that what I wrote as common interest among theoreticians is not necessarily common among theoreticians in the other fields.

References

Aoki K (2010) Evolution of the social-learner-explorer strategy in an environmentally heterogeneous two-island model. Evolution 64:2575–2586

Aoki K, Nakahashi N (2008) Evolution of learning in subdivided populations that occupy environmentally heterogeneous sites. Theor Popul Biol 74:356–368

Aoki K, Wakano JY, Lehmann L (2012) Evolutionarily stable learning schedules and cumulative culture in discrete generation models. Theor Popul Biol 81:300–330

Arbilly M, Motro U, Feldman MW, Lotem A (2010) Co-evolution of learning complexity and social foraging strategies. J Theor Biol 267:573–581

Biesmeijer JC, Seeley TD (2005) The use of waggle dance information by honey bees throughout their foraging careers. Behav Ecol Sociobiol 59:133–142

Borenstein E, Feldman MW, Aoki K (2008) Evolution of learning in fluctuating environments: when selection favors both social and exploratory individual learning. Evolution 62:586–602

Boyd R, Richerson PJ (1985) Culture and the evolutionary process. University of Chicago Press, Chicago

Enquist M, Eriksson K, Ghirlanda S (2007) Critical social learning: a solution to Rogers' paradox of nonadaptive culture. Am Anthropol 109:727–734

Feldman MW, Cavalli-Sforza LL (1984) Cultural and biological evolutionary processes: gene-culture disequilibrium. Proc Natl Acad Sci U S A 81:604–607

Feldman MW, Aoki K, Kumm J (1996) Individual versus social learning: evolutionary analysis in a fluctuating environment. Anthropol Sci 104:209–232

Henrich J (2004) Demography and cultural evolution: how adaptive cultural processes can produce maladaptive losses–the Tasmanian case. Am Antiquity 69:197–214

Henrich J, Boyd R (1998) The evolution of conformist transmission and the emergence of between-group differences. Evol Hum Behav 19:215–241

Izquierdo LR, Izquierdo SS (2008) Dynamics of the Bush–Mosteller learning algorithm in 2×2 games. In: Weber C, Elshaw M, Mayer NM (eds) Reinforcement learning: theory and applications. Austria: I-Tech Education and Publishing, Vienna

Kameda T, Nakanishi D (2002) Cost-benefit analysis of social/cultural learning in a nonstationary uncertain environment: an evolutionary simulation and an experiment with human subjects. Evol Hum Behav 23:373–393

Kobayashi Y, Aoki K (2012) Innovativeness, population size, and cumulative cultural evolution. Theor Popul Biol 82:38–47

Kobayashi Y, Wakano JY (2012) Evolution of social versus individual learning in an infinite island model. Evolution 66:1624–1635

Lehmann L, Wakano JY (2013) The handaxe and the microscope: individual and social learning in a multidimensional model of adaptation. Evol Hum Behav 34:109–117

Lehmann L, Feldman MW, Kaeuffer R (2010) Cumulative cultural dynamics and the coevolution of cultural innovation and transmission: an ESS model for panmictic and structured populations. J Evol Biol 23:2356–2369

Lehmann L, Wakano JY, Aoki K (2013) On optimal learning schedules and the marginal value of cumulative cultural evolution. Evolution 67:1435–1445

Lumsden C, Wilson EO (1981) Genes, mind, and culture. Harvard University Press, Cambridge

Nakahashi W, Wakano JY, Henrich J (2012) Adaptive social learning strategies in temporally and spatially varying environments. Hum Nat 23:386–418

Rendell L, Fogarty L, Laland KN (2010) Rogers' paradox recast and resolved: population structure and the evolution of social learning strategies. Evolution 64:534–548

Rogers AR (1988) Does biology constrain culture? Am Anthropol 90:819–831

Wakano JY, Aoki K (2006) A mixed strategy model for the emergence and intensification of social learning in a periodically changing natural environment. Theor Popul Biol 70:486–497

Wakano JY, Aoki K (2007) Do social learning and conformist bias coevolve? Henrich and Boyd revisited. Theor Popul Biol 72:504–512

Wakano JY, Kawasaki K, Shigesada N, Aoki K (2011) Coexistence of individual and social learners during range-expansion. Theor Popul Biol 80:132–140

Wakano JY, Miura C (2013) Trade-off between learning and exploitation: The Pareto-optimal versus evolutionarily stable learning schedule in cumulative cultural evolution. Theor Popul Biol, in press, doi: 10.1016/j.tpb.2013.09.004

Index

T. Akazawa et al. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-54511-8, © Springer Japan 2013